Three Essays on Growth and Competitiveness of the Chinese Economy

By

María Jesús Herrerías Talamantes

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR IN ECONOMICS AT UNIVERSITAT JAUME I DE CASTELLÓ

JANUARY 2010

Supervisor: Dr. Vicente Orts Ríos

Table of Contents

Pages

List of Tables 5

List of Figures 8

Acknowledgements 9

Spanish Preface 15

English Preface 28

Chapter I: The Chinese Economic Growth: A Reappraisal

1.1 Introduction 40

1.2 Overview of the Literature 44

1.3 Econometric Methodology and Data 49

1.4 Empirical Analysis 51

1.4.1 Deterministic Components

1.4.2 Productivity Model

1.4.2.1 Long-Run Identification

1.4.2.2 Short-Run Identification

1.4.3 Output Model

1.4.3.1 Long-Run Identification

1.4.3.2 Short-Run Identification

1.5 Comments and Conclusions 61

Appendix 1A **65**
Appendix 1B **67**
References **74**

Chapter II: Equipment Investment, Output and Productivity in China

2.1 Introduction **78**
2.2 Literature Review **82**
2.3 Data and Methodology **87**
2.4 Empirical Results **90**
2.5 Conclusions **100**
Appendix 2A **103**
Appendix 2B **107**
References **112**

Chapter III: The Driving Forces Behind China's Growth

3.1 Introduction **116**
3.2 An Overview of the Literature **119**
3.3 A Time Series Analysis of Chinese Growth **127**
a) Unit Root Tests
b) Cointegrating Relationships
3.4 Empirical Results **133**
a) Long-Run Effects
b) Short-Run Effects
3.5 Conclusions **139**
Appendix 3A **142**
Appendix 3B **144**

References 148

Chapter IV: Weighted Convergence and Regional Clusters across China

4.1 Introduction 152

4.2 Emerging patterns in provincial distribution of per capita GDP in China: 1952-2005 157

4.3 Per Capita income convergence as distribution dynamics 160

4.3.1 Intra-distribution mobility and ergodic distributions

4.3.2 Transition path analysis and mobility indices

4.3.3 The evolution of the external shape of the distributions

4.3.4 Conditioning on neighbour-relative information

4.4 Results 170

4.4.1 Unweighted analysis

4.4.2 Weighted analysis

4.4.3 Conditioning: spatial analysis

4.5 Conclusions 180

Appendix 4A 184

References 195

List of Tables

Chapter I: The Chinese Economic Growth: A Reappraisal

Table 1: Short-Run Identification
Table 1A.1: Unit Root Tests
Table 1A.2: Determination of the Rank Test in the Productivity Model
Table 1A.3: Determination of the Rank Test in the Output Model
Table 1B.1: Dynamics of Labour Productivity and Output.

Chapter II: Equipment Investment, Output and Productivity in China.

Table 1: Base Models Output and Labour Productivity
Table 2: Augmented Models with Human Capital
Table 3: Augmented Models with Infrastructures
Table 2A.1: Unit Root Tests
Table 2A.2: Weakly Exogeneity Tests
Table 2A.3: Determination of the Rank Test and the Roots of the Companion Matrix. Productivity Model.
Table 2A.4: Determination of the Rank Test and the Roots of the Companion Matrix. Output Model
Table 2A.5: Determination of the Rank Test and the Roots of the Companion Matrix. Productivity Model, Augmented with Human Capital
Table 2A.6: Determination of the Rank Test and the Roots of the Companion Matrix. Output Model, Augmented with Human Capital

Table 2A.7: Determination of the Rank Test and the Roots of the Companion Matrix. Productivity Model, Augmented with Infrastructure (rprail)
Table 2A.8: Determination of the Rank Test and the Roots of the Companion Matrix. Output Model, Augmented with Infrastructure (rprail)
Table 2A.9: Determination of the Rank Test and the Roots of the Companion Matrix. Output Model, Augmented with Infrastructure (rphigh)
Table 2A.10: Percentage of Equipment and Machinery Imported to Total Imports.
Table 2B.1: Dynamics of Equipment Investment on output growth.
Table 2B.2: Causality test in the short and long run.
Table 2B.3: Variance Decomposition of *lgdp*

Chapter III: The Driving Forces Behind China's Growth.

Table 1: Unit Root Tests
Table 2: Cointegrating Long-Run Relationships.
Table 3: Short-Run Dynamics
Table 3A.1: Unit Roots
Table 3B.1: GDP Model with Trade to GDP model
Table 3B.2: GDP Model with Exports to GDP model
Table 3B.3: GDP Model with Imports to GDP model
Table 3B.4: GDP Model with Human Capital and Trade to GDP model
Table 3B.5: GDP Model with Human Capital and Exports to GDP model
Table 3B.6: GDP Model with Human Capital and Imports to GDP model
Table 3B.7: Labour Productivity Model with Trade to GDP model
Table 3B.8: Labour Productivity Model with Exports to GDP model
Table 3B.9: Labour Productivity Model with Imports to GDP model
Table 3B.10: Labour Productivity Model with Human Capital and Trade to GDP model
Table 3B.11: Labour Productivity Model with Human Capital and Exports to GDP model
Table 3B.12: Labour Productivity Model with Human Capital and Imports to GDP model

Chapter IV: Weighted Convergence and Regional Clusters across China

Table 4A.1: Descriptive Statistics for Chinese Provinces, Per Capita Income (GDP/N) And Population (N), 1952-2005

Table 4A.2 Transition Probability Matrix and Ergodic Distribution, Per Capita Income (GDP/N), unweighted

Table 4A.3 Transition Probability Matrix and Ergodic Distribution, Per Capita Income (GDP/N), GDP-weighted

Table 4A.4 Transition Probability Matrix and Ergodic Distribution, Per Capita Income (GDP/N), population-weighted

Table 4A.5 Transition Probability Matrix and Ergodic Distribution, Per Capita Income (GDP/N), physically contiguous-conditioned

Table 4A.6 Mobility Indices

Table 4A.7 Transition Path Analysis

List of Figures

Chapter IV: Weighted Convergence and Regional Clusters across China

Figure 4.1: GDP/N, densities, 1952 vs 1978 vs 2005
Figure 4.2: GDP/N, densities, unweighted vs. GDP-weighted
Figure 4.3: GDP/N, densities, unweighted vs. population-weighted
Figure 4.4: GDP/N, densities, unweighted vs. physically contiguous-conditioned
Figure 4.5: GDP/N, ergodic distributions, 1952-1978 vs 1978-2005

Acknowledgements

Although this section of my Doctoral Thesis is undoubtedly the most gratifying of all to write, it is also the part that frightens me the most as I don't want to leave anybody out. Let me begin, then, by explaining that there are three fundamental groups I would like to thank for their support and patience as I have walked this long, and sometimes lonely, path towards my Doctor's Degree.

Without a doubt, the first group I must give thanks to is what I would call the *academics*. Perhaps the most important and influential person in all my undertakings over these past four years has been my Doctoral Thesis Supervisor, Vicente Orts. I can only admire him for the stamina and enthusiasm he has displayed as this Thesis was being researched and written, even though he had to find the time to continue to perform his other administrative and research duties with other colleagues. Right from the very beginning he became fully involved not only in the production of each chapter of this Thesis but also in other research work we have conducted together. I must also express my gratitude to him for systematically offering me absolute freedom in each of the aspects I have chosen to work on in my short career as a researcher and for having always believed in me. This was the case from the moment the topic of this Thesis was chosen (despite the Chinese economy being unknown territory for both of us) to my joining the two research projects funded by the Spanish Ministry of Education and Science that he himself directs and which have provided me with a scholarship without which I would not have been able to reach the point I find myself today. He did not hesitate to provide me with all the resources he had available to him in order to help me arrange my three research visits, where I was able to learn new methodologies with prominent experts such as Soren Johansen and Katerina Juselius, among others. Although, if I'm not mistaken, he has only been with me to one conference, this has not prevented him from aiding and encouraging me to attend national and international congresses, where I was able to meet different professionals from my field of study and which has later helped generate spillovers into other types of activities. So, it is not surprising that I consider him to be one of my best friends, even though we might argue from time to time, but in the end we always get over it and things soon return to normal. As you know, Vicente, these past two years have been a difficult time for me and I am therefore even more grateful for everything all your help.

I also want to thank Emili Tortosa, who has joined the group of people interested in the Chinese economy, because, quite simply, without his assistance I would not have been able to finish my Doctoral Thesis. I am also grateful to all my colleagues at the Economics Department of the Universitat Jaume I who have encouraged and helped me in what seemed at first to be an utterly ridiculous idea and has now become a fully fledged reality. Nevertheless, my continuous trips abroad, either on research visits or to attend conferences, have allowed me to meet other colleagues and friends from different places around the world who have given me their support in this work. Of all these wonderful people, a special mention goes to Wing Thye Woo, Yanrui Wu, Guy Liu, John Weiss, Vera Troeger, Heino Nielsen and Katerina Juselius, among others, but especially to my friend Jun Zhang, who is currently going through a rather hard time in his life. Finally, my gratitude also goes to our translator, Mark, who has to try to make sense of our *Spanglish* and undoubtedly improves our work. Thank you.

Institutional aid has also played an essential role and is the second group I wish to thank for its help and support. First of all, I am indebted to the Universitat Jaume I for enabling me to join the Economics Department, and also to its Director, Miguel Albert, for being flexible and understanding with me when I needed it and for helping me organise the 1st Cycle of Conferences on Economics and Development, which was held in 2009. I am also grateful for having had the chance to teach on the Business Administration and Management Degree course for two years. Secondly, thanks are due to the Generalitat Valenciana for awarding me a pre-doctoral scholarship for a period of four years, plus two other grants that allowed me to carry out visits to prominent research centres abroad. Finally, I am also grateful to the *Chinese Economic Association UK/Europe* for the three invitations I have received in the last three years to present my work at its annual conference that is held in China, more specifically at Fudan University (Shanghai), Zheijiang University (Hangzhou) and Renmin University (Beijing). These have been wonderful opportunities to experience and gain a better understanding of Chinese life, society and culture, which I find so fascinating.

Likewise, I would also like to express my gratitude to all those people who, at some time or another, have offered their suggestions and comments or even harsh criticism about my work, since thanks to them the final outcome has been improved. I am particularly indebted to those who attended the *Chinese Economic Association UK/Europe, The Chinese Economists Society, International forum for Contemporary Chinese Studies, Jornadas de Economía Internacional, Simposio de Análisis Económico, CERDI, ETSG,* and the *Spring Meeting of Young Economists*.

Last, but by no means whatsoever least, in fact I would say quite the contrary, I wish to mention my *family* and *my friends*. Without a shadow of a doubt, the encouragement and backing of my parents has been essential, because my renowned (as claimed by some) perseverance, capacity for work and determination are traits that I inherited from them. This Thesis is written in memory of my father, Manuel, and my aunt, Luisa, who looked after me since I was little and was therefore like a second mother to me. In the end, little children grow up and become adults and then it eventually becomes our job to look after our elders until they unfortunately have to leave us. There are diseases that cannot be cured with the means we have available today, and it is only by promoting research that we can hope to find a solution and put a stop to them. To my mother, Rosario, an outstanding woman, with the greatest capacity to adapt to changing circumstances I have ever seen. Mum, this Thesis is dedicated to you, even though you’re not too sure what my work is really all about. Tere, Laurita and Roda – thanks for standing by me in both the good and the not-so-good times.

My most heartfelt thanks to everybody, and please think of this Thesis as your own because without you I would never have been able to finish it.

María Jesús Herrerías Talamantes

In Memory of my father and my aunt

Dedicated to my mother

Spanish Preface

1. Objeto y Objetivos de la Investigación

El objeto de esta Tesis Doctoral es analizar los determinantes del crecimiento económico y competitividad de la economía China e investigar si diferenciales de renta per capita entre sus diferentes regiones tienden a un proceso de convergencia o divergencia durante las últimas cuatro décadas.

Los objetivos específicos de la investigación llevada a cabo son los siguientes:

a) Revisión del papel desempeñado por las exportaciones y la inversión en el proceso de crecimiento de la economía China en las últimas cuatro décadas aplicando la metodología del modelo VAR.

b) Analizar específicamente el efecto de la inversión en equipamiento junto con otros factores de crecimiento como las exportaciones, infraestructuras, actividades de innovación y capital humano sobre el nivel de output y productividad del trabajo en la economía China.

c) Re-examinar el orden de integrabilidad de las tasas de crecimiento del output y la productividad con tests de raíces unitarias más recientes que consideran por ejemplo la posibilidad de cambios estructurales y que mejoran la especificación del modelo comparado con los tests más tradicionales. Además, se investiga los potenciales determinantes de las tasas de crecimiento del output y la productividad con el objetivo de distinguir si el proceso de crecimiento de la economía China es más consistente con un modelo *à la* Solow o con los modelos de crecimiento endógeno.

d) Examinar a nivel regional si las provincias más pobres en China tienden a un proceso de convergencia (divergencia) respecto a las más ricas o si se están formando clusters regionales en términos de renta per cápita. Además se examina la existencia de spillovers regionales.

2. Planteamiento y Metodología Utilizada

2.1 Planteamiento: Estructura de la Tesis

Para abordar los objetivos planteados, la Tesis se ha estructurado en cuatro capítulos:

En el Capítulo I, se re-examina a modo de introducción la problemática planteada por la literatura existente sobre el crecimiento económico en China con técnicas de cointegración. En primer lugar se analiza la influencia de las exportaciones y la inversión en el output y productividad de la economía China para el periodo 1962-2004. Se trata de clarificar si la economía China ha seguido un proceso de *export-led growth* o, por el contrario, el rápido crecimiento de la economía China responde más a una pura acumulación de capital físico en línea con los trabajos ya existentes. Además se realiza una extensión, investigando el papel de las importaciones en el crecimiento de la economía China.

En el Capítulo II se analiza en detalle y se aporta nueva evidencia a la literatura del papel que ha desempeñado la inversión en bienes de quipo sobre el output y productividad de la economía China para el mismo periodo. Además, se ofrece evidencia de la contribución de las infraestructuras y el capital humano. En el apéndice se aporta evidencia empírica de la robustez del efecto de los bienes de equipo sobre el output.

En el Capítulo III, en primer lugar, se re-examina el orden de integración de las tasas de crecimiento del output y la productividad con nuevos y más recientes tests de raíces unitarias y, en segundo lugar, se analiza el papel desempeñado por los potenciales determinantes del crecimiento económico que se han destacado en los modelos de tipo AK o Schumpeterianos. Básicamente nos centramos en la acumulación de capital físico y humano, las actividades de innovación y la apertura comercial y competitividad a lo largo del periodo 1962-2000.

Finalmente, en el Capítulo IV se analiza a nivel regional las diferencias en renta per capita observadas entre las diferentes provincias Chinas, y en particular se investiga si dichas diferencias tienden a desaparecer a lo largo del tiempo, es decir, existe una tendencia a la convergencia de la renta per capita regional o por el contrario dichas diferencias tienden a incrementarse. Para realizar este análisis para el periodo 1952-2005, se tendrá en cuenta, a diferencia de otros trabajos, el tamaño de cada provincia medido tanto por la población como por el nivel de actividad, así mismo se analiza el efecto de la localización espacial sobre la convergencia, condicionando la información de cada provincia por la correspondiente a las provincias que hay a su alrededor, con el objetivo de examinar la existencia de spillovers en el proceso de crecimiento.

2.2 Metodología Utilizada

En esta Tesis Doctoral se han empleado dos metodologías diferentes. Para los tres primeros Capítulos que estudian la economía China a nivel nacional, se ha empleado el modelo VAR Cointegrado, y para el cuarto Capítulo se ha empleado una aproximación no paramétrica, en particular hemos hecho uso de las matrices de transición e índices de movilidad, así como de las distribuciones de densidad de Kernel.

La metodología del Modelo VAR Cointegrado se ha considerado apropiada para el análisis porque nos proporciona información tanto de los efectos económicos a corto como a largo plazo. Además, dada la interdependencia que existe entre los diferentes determinantes del crecimiento con el output y la productividad se ha considerado conveniente realizar una estimación conjunta de las variables para evitar así el problema de la endogenidad y determinar la dirección de causalidad entre las variables objeto de estudio.

Por su parte, la aproximación no paramétrica para el análisis de la convergencia de las diferentes regiones de China, tiene la ventaja de evadir las críticas que Quah (1993) pone de relieve sobre las estimaciones cross-section y de datos de panel. Además mediante las matrices de transición y las distribuciones de Kernel, el investigador no impone la forma funcional en el modelo y por lo tanto deja que los datos indiquen la naturaleza de la relación de interés. Finalmente, mediante estos dos instrumentos se permite capturar toda la forma de la distribución y revelar sus cambios.

3. Aportaciones Originales

La contribución de nuestro trabajo a la literatura ha sido la siguiente:

a) En primer lugar, se confirma que en el caso de China la inversión tiene efectos a largo plazo sobre el nivel de output y productividad, y en particular, entre los componentes de la acumulación de capital, hemos encontrado evidencia empírica adicional de que la inversión en bienes de equipo y las infraestructuras han desempeñado un papel relevante en el proceso de crecimiento en China. Estos resultados estarían más en línea con la versión Schumpeteriana del crecimiento endógeno que con el modelo de Solow.

b) También se aporta nueva evidencia del papel de las importaciones como factor adicional y complementario al de las exportaciones, en el crecimiento de la economía China.

c) Nuestros resultados indican que la dirección de la causalidad de las variables de interés en China va de la inversión y el comercio al output y la productividad, debido a que la inversión, aunque es endógena, a largo plazo no se ve afectada en ningún caso por el output y la productividad y a que las variables de comercio son débilmente exógenas. Así mismo, no se encontró evidencia de que el comercio afectara a la inversión. Estos resultados se contradicen con la evidencia empírica que se encontró para algunos países asiáticos en los años sesenta por Rodrik (1995).

d) A largo plazo la inversión en capital humano y las actividades de innovación y desarrollo tienen efecto positivo sobre las tasas de crecimiento del PIB y productividad.

e) Empleando tests de raíces unitarias más recientes, se observa que las tasas de crecimiento del output y la productividad poseen raíz unitaria. Este resultado es relevante por sus implicaciones desde el punto de vista de la teoría económica, así como por sus implicaciones desde el punto de vista de la especificación del modelo empírico.

f) Aportar evidencia de la existencia de un efecto positivo a largo plazo del tipo de cambio real, como medida de la competitividad, sobre output y productividad. Además, este efecto puede considerarse robusto, ya que es una regularidad empírica que se mantiene en cada uno de los modelos analizados.

g) En el análisis provincial, se aporta nueva evidencia de la existencia de divergencia durante la pre-reforma (1952-1978) y de convergencia en la post-reforma (1978-2005), teniendo en cuenta tanto el tamaño de la población de cada una de las provincias analizadas como el nivel de actividad. Así mismo, se observa la existencia de convergencia una vez tenido en cuenta "el efecto vecino" de cada una de las provincias de China.

4. Conclusiones Obtenidas: Futuras Líneas de Investigación

4.1 Conclusiones y Comentarios Finales

En el primer Capítulo de mi Tesis Doctoral se muestra evidencia empírica de que tanto las exportaciones como la inversión han desempeñado un papel relevante en el proceso de crecimiento de la economía China. Además, de nuestros resultados también se desprende que las actividades de innovación han estimulado la inversión en el largo plazo. Ambos resultados son robustos a diferentes especificaciones.

Sin embargo, sin poner en duda el significativo papel que han jugado las exportaciones y la inversión, la teoría del crecimiento endógeno subraya el rol de las importaciones más que de las exportaciones en el proceso de crecimiento de una economía a través del acceso de bienes de capital e intermedios importados, que son una fuente importante de transferencia de tecnología avanzada, y es crucial principalmente en los países en vías de desarrollo. En el caso de la economía China, las importaciones de bienes de capital y bienes intermedios de países con un nivel avanzado de tecnología ha sido determinante para acelerar y garantizar el proceso de industrialización. Esta es la mayor motivación que nos llevó a realizar una extensión en el primer capítulo analizando el rol de las importaciones sobre el output y la productividad en China, y clarificar la dirección de la causalidad entre las importaciones y el nivel de actividad.

Nuestros resultados indican que las importaciones al igual que la inversión afectan al desarrollo económico de la economía China, encontrando lo que se ha venido denominando en la literatura un efecto de *import-led growth*. Este resultado es robusto a diferentes especificaciones del modelo.

No obstante, de la teoría económica, los economistas sabemos que el efecto permanente de la acumulación de capital depende en buena medida de los determinantes de la acumulación de capital y si predominan entre ellos los factores de oferta o los de demanda. Es bien sabido que únicamente deberíamos esperar efectos positivos de la acumulación de capital a largo plazo sobre el output y la productividad si predominan entre sus determinantes los factores de oferta, debido al progreso tecnológico incorporado que existe en la acumulación de capital. Bajo esta premisa, se elaboró el segundo de los Capítulos de mi Tesis Doctoral, examinando uno de los componentes de la acumulación de capital como es la inversión en equipamiento. Además incorporamos otros factores de crecimiento que la literatura ha puesto de relieve como las infraestructuras, las exportaciones, el capital humano y las actividades de innovación. Nuestros resultados sugieren que tanto los bienes de equipo como las exportaciones son factores relevantes a la hora de explicar el output y la productividad a largo plazo en China, incluso controlando por otras fuentes de crecimiento en el periodo considerado. Además encontramos que la dirección de la causalidad es unidireccional y que va de la inversión en bienes de equipo y exportaciones al output y productividad del trabajo. Cuando se introdujo en el modelo las infraestructuras y el capital humano, nuestros resultados indicaron que también son factores relevantes en la dinámica del output y la productividad del trabajo a largo plazo. Como en casos anteriores, el efecto de la inversión en bienes de equipo sobre el nivel de actividad es robusto a diferentes especificaciones del modelo. Esta aproximación, sin ser determinante, avala la existencia de una vía de incorporación de mejoras tecnológicas a través de la inversión, lo que junto al efecto positivo del capital humano sobre el output y la productividad e I+D, estarían en consonancia con las hipótesis de que estos factores han jugado un papel importante en el proceso de crecimiento. De hecho nuestros resultados estarían en línea con los modelos que integran modelos de corte Schumpeteriano y modelos *à la* Solow-Swan, como los desarrollados por Aghion y Howitt (1998).

En el Capítulo 3, el objetivo principal de este trabajo ha sido desentrañar la relevancia de los modelos de crecimiento endógeno en la explicación del crecimiento económico de China desde 1965 hasta 2000, tanto por las consecuencias de política económica de este tipo de modelos como por su relevancia empírica. En concreto, se han explorado las propiedades de las series temporales de las tasas de crecimiento del PIB y la productividad del trabajo. Además se ha investigado el papel desempeñado tanto por la acumulación de capital físico y humano como su interacción con otras fuentes de crecimiento económico, como la apertura al comercio, los gastos de I+D y la competitividad en el corto y largo plazo. Además, para examinar la robustez de nuestros resultados, se consideraron tres medidas alternativas de comercio (exportaciones, importaciones y comercio en general con el PIB).

De nuestros resultados se desprende en primer lugar, que las tasas de crecimiento del output y la productividad no son estacionarias, es decir, exhiben movimientos persistentes. Además, los resultados indican que la tasa de acumulación de capital, entendida en un sentido amplio, incluyendo tanto capital físico como humano) es una de las fuentes de crecimiento más importantes en la economía China. Además, de acuerdo con las diferentes extensiones de los modelos de crecimiento endógeno, se encontró que el nivel de los recursos incorporados en las actividades de I + D y la apertura comercial (independientemente de la medida utilizada: el comercio, las exportaciones o importaciones) influyen positivamente en las tasas de crecimiento del output y productividad del trabajo en el largo plazo. Por último, se encontró evidencia de que el mantenimiento de un tipo de cambio real "competitivo" también ha desempeñado un papel importante en la explicación de las tasas de crecimiento del output y productividad del trabajo en el período que se analiza. Estos resultados, considerados en conjunto, nos permiten afirmar que el proceso de crecimiento experimentado por la economía China no sólo ha sido el resultado de un proceso de acumulación de factores, sino que esta acumulación de factores ha coexistido con un significativo aumento de la eficiencia en el largo plazo. Así pues, aunque es difícil distinguir estrictamente entre diferentes modelos de crecimiento, los resultados parecen ser más coherentes con las implicaciones de ciertas versiones de los modelos de crecimiento endógeno que con los modelos de crecimiento *à la* Solow.

En el último Capítulo de mi Tesis Doctoral se han examinado si las diferencias regionales en términos de renta per capita tienden a desaparecer o por el contrario dichas diferencias son persistentes a lo largo del periodo analizado (1952-2005). De nuestros resultados se desprende que existen dos comportamientos diferentes en el periodo considerado. De 1952 a 1978 existe una clara tendencia de las provincias a estar entre los estados de rentas más pobres, mientras ocurre lo contrario en el periodo de la post-reforma. Estos resultados se confirman y se acentúan aun más, al tener en cuenta tanto la población de cada provincia como su nivel de actividad en el proceso de convergencia en términos de renta per capita. Aunque el patrón encontrado es convergencia, este coexiste durante todo el periodo con pequeños clusters cuyo comportamiento es diferente al promedio del resto de las provincias en China. Finalmente, cuando se tienen en cuenta aspectos de localización geográfica, nuestros resultados muestran cierto grado de convergencia entre clusters, lo que parece indicar que las externalidades espaciales son relevantes en la convergencia de las provincias de China, aunque persiste la clara bi-modalidad durante el periodo considerado. Estos resultados son relevantes por sus implicaciones de política económica regional.

Aunque desde la perspectiva de incrementar su tasa de crecimiento económico, la estrategia de desarrollo económico perseguido por las autoridades Chinas ha sido exitosa, hay profundos problemas estructurales que pueden ser una fuente de limitaciones y cada vez mayores en el futuro, lo que requiere matizar nuestras conclusiones. En primer lugar, el notable proceso de crecimiento tiene que ser traducido en mejoras en la distribución de la renta y en el bienestar económico de la población. Estos objetivos son incompatibles con la estrategia mantenida durante buena parte del periodo considerado de mejora de las zonas costeras y urbanas en detrimento de las rurales (aumento de la desigualdad de la renta interregional) y con la opción política de hacer hincapié en el peso de la inversión en detrimento del consumo en la composición del PIB.

En segundo lugar, aunque se encontró evidencia de que el capital físico es una fuente de crecimiento a largo plazo en China, la sostenibilidad de las altas tasas de ahorro e inversión es dudosa, no sólo porque esta estrategia tiene costes significativos en términos de niveles bajos de consumo, sino porque en el futuro podría afectar a la productividad del capital y la eficiencia de la inversión. Así, a pesar de su efecto positivo sobre la tasa de crecimiento, no parece factible dejar sólo en manos de aumentos en las tasas de ahorro e inversión el crecimiento de China, máxime cuando estas tasas en futuro incluso podrían descender. Por consiguiente, este escenario afectará el ritmo de la innovación tecnológica que se ha incorporado al stock de capital instalado y puede debilitar las fuerzas que contrarrestan la tendencia a la disminución de los rendimientos en la acumulación de capital. Sin embargo, desde nuestro punto de vista existen algunas posibles opciones para contrarrestar esta tendencia. Es bien sabido que existen importantes desigualdades entre las provincias en China, y si nos fijamos en la variación regional en la estructura del capital, podemos observar que está fundamentalmente ubicada en las provincias costeras. Así, en principio, una posibilidad que permite continuar con la política de inversión antes mencionada es redistribuir las nuevas inversiones en las provincias menos desarrolladas de China. Sin embargo, esta posibilidad no está libre de riesgos y dificultades, sobre todo porque sería necesario invertir algunas de las tendencias que han resultado de la combinación de políticas intervencionistas, junto con una mayor orientación a una economía de mercado.

Desde otro punto de vista, dado que hemos encontrado que el capital humano y la innovación ejercen una influencia positiva y directa en el crecimiento económico, y que estos dos factores clave son relativamente escasos en la economía China, tanto en términos absolutos como cuando se comparan con los países desarrollados, todavía hay un margen considerable para estimular la innovación tecnológica y la acumulación de capital humano, mientras que al mismo tiempo se logra un crecimiento más equilibrado y sostenible.

Por último todo parece indicar que, las diversas reformas que han puesto en marcha para facilitar la integración de China en los mercados internacionales y que ha convertido a la economía China en uno de los mayores comerciantes del mundo, han dado buenos resultados. Sin embargo, las altas tasas de inversión han intensificado su dependencia del capital y bienes intermedios importados, lo que además de debilitar la demanda interna, tiene como consecuencia una creciente dependencia exterior. Esto, a su vez, ha aumentado la necesidad de altos niveles de exportaciones a fin de suavizar la restricción externa. Hasta ahora, esta necesidad de elevadas exportaciones, no parece haber sido un problema, pero hay algunos críticos que creen que el mantenimiento del ritmo actual de crecimiento de las exportaciones no es sostenible, porque depende de la capacidad de la demanda extranjera de absorber los productos Chinos y hace que la economía esté más expuesta a los shocks externos.

Esta última consideración también pueden verse afectada por la sostenibilidad de la política de tipo de cambio. Así, aunque hasta ahora el mantenimiento de un tipo de cambio competitivo parece haber servido como un estímulo para el crecimiento, parece difícil que se mantenga sistemáticamente a causa de los desequilibrios que esta estrategia implica en términos de acumulación de reservas y sus implicaciones para la gestión de la política monetaria.

Aunque de nuestros resultados en el análisis regional se concluya que durante la pre-reforma la tendencia haya sido la de la divergencia en términos de renta per capita, y durante la post-reforma la de convergencia, hay que aclarar que estas dos tendencias opuestas han coexistido con una clara estratificación de las provincias Chinas en diferentes clubs. Este fenómeno no es de menor preocupación para las autoridades Chinas, y avalan que aún exista cierto margen para promover políticas económicas encaminadas a estimular la convergencia en términos de PIB per cápita entre las provincias de China, dado que la tendencia natural a la aglomeración espacial parece persistente. Así, junto a la articulación de las políticas regionales y a la dimensión regional de otras políticas del gobierno central tendentes a equilibrar el desarrollo regional (proyectos de inversión central, la dotación de infraestructuras, la política de crédito, etc), son necesarias otro tipo de medidas más específicas para equilibrar la tendencia a la aglomeración de la actividad económica inducida por las fuerzas del mercado y alcanzar un crecimiento más equilibrado y sostenible (por ejemplo tendentes a reconsiderar la movilidad interprovincial).

Para concluir, si bien nuestros resultados sugieren que hay señales de un avance exitoso en el crecimiento de la economía china en el pasado, con ganancias significativas en eficiencia, subsisten profundos problemas estructurales, a los que hay que añadir los que ha generado el propio proceso de crecimiento, por lo que es necesario introducir más reformas económicas a fin de garantizar la sostenibilidad del crecimiento económico y el desarrollo en el futuro.

4.2 Futuras Líneas de Investigación

Las futuras líneas de investigación, que algunas de ellas en buena medida ya se están llevando a cabo, se pueden dividir en dos grandes grupos: a nivel nacional y a nivel provincial y de ciudad.

a) A nivel Nacional:

En primer lugar, dado que de mis resultados de investigación se desprende que tanto las exportaciones como las importaciones han jugado un papel determinante, aunque por diferentes mecanismos, en el proceso de crecimiento de la economía China, se está trabajando en profundizar este análisis y considerar ya no el total de las exportaciones e importaciones, sino las exportaciones de manufacturas y las importaciones de capital, ya que todo parece indicar que son los verdaderos motores del crecimiento de la economía China en las últimas cuatro décadas.

En segundo lugar, dado que se ha encontrado una regularidad respecto al tipo de cambio real y su efecto sobre el output y la productividad, se van a estudiar los desajustes del tipo de cambio real del Yuan respecto a distintas monedas, utilizando las diferentes aproximaciones que la literatura ha puesto de relieve. Este extremo creemos que es de gran transcendencia tanto para la economía China como para el resto del mundo, tal y como ha puesto de relieve la actual crisis económica y las posibles estrategias de salida de la misma.[1]

b) A nivel Espacial:

La primera línea de trabajo en el análisis espacial, y con mucha más desagregación de los datos, corresponde al análisis de la convergencia o divergencia en términos de renta per capita de las diferentes provincias de la economía China. Se pretende seguir profundizando en el aspecto de los diferenciales de renta observados entre provincias Chinas. Siguiendo la metodología no paramétrica de Quah (1993) hemos realizado un análisis de la convergencia de las regiones Chinas y la formación de clusters regionales utilizando únicamente la renta per cápita, concluyendo que durante la pre-reforma (1952-1978) la renta per cápita de las provincias Chinas tendían a divergir mientras durante la post-reforma (1978-2005) se observa el efecto contrario, es decir, las provincias más pobres tienden a crecer más rápido que las ricas, lo que provoca un efecto de convergencia entre las diferentes regiones. Sin embargo, y es lo que se pretende analizar a continuación, es si esa convergencia se produce debido a ganancias de productividad o por incrementos en la intensidad de capital. Dicho análisis se va a llevar a cabo tanto utilizando las distribuciones de densidad de Kernel como los índices de eficiencia y productividad propuestos por Kumar y Rusell (2002). Este punto es crucial para entender la sostenibilidad del crecimiento regional en la economía China.

La segunda línea de trabajo, se basa en realizar una extensión sobre el análisis de convergencia previo, con el objetivo de diferenciar si cada una las provincias Chinas convergen, divergen o están *caching up* respecto al nacional de China o por el contrario existen pequeños clusters regionales. Dicho análisis se realizará en un contexto de análisis de series temporales de 1952 a 2007. La ventaja de esta aproximación respecto a la anterior consiste en que es capaz de diferenciar el comportamiento de cada provincia respecto al nacional de China o respecto a los clusters encontrados, proporcionando información relevante de cara al desarrollo de políticas económicas concretas para estimular una determinada región.

[1] Ver en este sentido las recientes opiniones de Blanchard en Finanzas y Desarrollo (Septiembre, 2009). FMI

En la tercera línea de investigación se pretende profundizar en el análisis de los aspectos geográficos y de localización de las diferentes provincias Chinas. De esta manera, en primer lugar se está desarrollando un indicador del "*Market Potential*" de cada una de las provincias Chinas entre 1952 y 2007 y posteriormente se realizará una aplicación empírica utilizando la metodología de los datos de panel para investigar los potenciales determinantes del crecimiento regional en China, teniendo en cuenta tanto el aspecto de la localización como la heterogeneidad de las provincias Chinas.

English Preface

1. Purpose and Aims of the Research

The purpose of this Doctoral Thesis is to analyse the factors determining the growth and increasing competitiveness of the Chinese economy, and to investigate whether differences in per capita income among the different regions of the country have tended towards a process of convergence or divergence over the last four decades.

The specific aims of the research are as follows:

a) To review the role played by exportations and investment in the process of growth in the Chinese economy over the last four decades by applying the VAR model methodology.

b) To analyse more specifically the effect of investment in equipment together with other growth factors like exports, infrastructures, innovation activities and human capital on the level of output and labour productivity in the Chinese economy.

c) To re-examine the order of integration of the rates of growth of output and productivity with more recent unit root tests that take into account, for example, the possibility of structural changes and which improve the specification of the model compared with the more traditional tests. Furthermore, the potentials determining these rates of growth of output and productivity are investigated with the aim of determining whether the process of growth of the Chinese economy is more consistent with a Solow-type model or with the endogenous growth models.

d) To examine, on the regional level, whether the poorer provinces in China tend towards a process of convergence (divergence) with respect to the wealthier ones or if regional clusters are being formed as regards per capita income. The existence of regional spillovers is also examined.

2. Procedure and Methodology Used

2.1 Procedure: Structure of the Thesis

In order to address the aims that were set, the Thesis is structured in four chapters, as follows.

Chapter I is an introductory section in which the problems posed by the literature concerning the economic growth in China are re-examined using cointegration techniques. First, the influence of exports and investment on the output and productivity of the Chinese economy is analysed for the period between 1962 and 2004. The aim of this analysis is to ascertain whether the economy in China has followed an export-led growth process or, in contrast, the fast growth of the Chinese economy is more the result of a pure accumulation of physical capital in line with the claims of existing research. An extension is also carried out to investigate the role of imports in the growth of the Chinese economy.

Chapter II offers new evidence and a detailed analysis of the role played by investment in equipment in the output and productivity of the Chinese economy for the same period of time. Additionally, evidence is also provided of the contribution made by infrastructures and human capital. The appendix provides empirical evidence of the robustness of the effect of equipment on output.

In Chapter III, first, the order of integration of the rates of growth of output and productivity are re-examined by means of new, more recent unit root tests and, second, we analyse the role played by the potentials determining the economic growth that have been highlighted in the AK- or Schumpeter-type models. Basically we focus on the accumulation of physical and human capital, innovation activities and the opening to trade and competitiveness throughout the period 1962-2000.

Finally, Chapter IV offers a regional-level analysis of the differences in terms of per capita income among the different provinces of China. More particularly, we investigate whether such differences tend to disappear over time, that is to say, if there is a tendency towards convergence of regional per capita income or, conversely, they tend to increase. To perform this analysis for the period 1952-2005, unlike other research works, we will take into account the size of each province in terms of both its population and the level of activity. Likewise, the effect of spatial location on convergence is also analysed by conditioning the information for each province with the data for the neighbouring provinces, the aim being to investigate the existence of spillovers in the growth process.

2.2 Methodology Used

Two different methodologies have been used in this Doctoral Thesis. For the first three chapters, which study the Chinese economy at national level, the Cointegrated VAR model was used, and for the fourth chapter a non-parametric approach was employed; more specifically we used transition matrices and mobility indices, as well as Kernel density distributions.

The Cointegrated VAR Model was considered suitable for the analysis because it provides us with information about the economic effects in both the short and the long term. In addition, given the interdependence that exists between the different factors determining growth, and output and productivity, it was deemed advisable to carry out a joint estimation of the variables in order to avoid the problem of endogeneity and to determine the direction of the causality among the variables under study.

The advantage of using the non-parametric approach to analyse the convergence of the different regions of China is that it allows us to dodge the criticisms that Quah (1993) points out with regard to the cross-section and panel data estimations. Moreover, by using transition matrices and Kernel distributions the researcher does not impose the functional form on the model and therefore allows the data to indicate the nature of the relationship of interest. Finally, with these two instruments it becomes possible to capture the whole distribution and to uncover its changes.

3. Original Contributions

Our work makes the following contributions to the literature:

a) First, it is confirmed that in the case of China, investment has long-term effects on the level of output and productivity and, in particular, among the components of capital accumulation we found additional empirical evidence that investment in equipment and infrastructures has played a significant role in the process of growth in China. These results would be more in line with the Schumpeterian version of endogenous growth than with the Solow model.

b) It also provides new evidence of the role of imports as an additional factor, complementing the factor *exports*, in the growth of the Chinese economy.

c) Our findings show that the causality of the variables of interest in China run from investment and trade to output and productivity, due to the fact that, despite being endogenous, in the long run investment is not at all affected by output and productivity and to the fact that the trade variables are weakly exogenous. Likewise, no evidence was found to show that trade affected investment. These findings contradict the empirical evidence that was found for some Asian countries in the sixties by Rodrik (1995).

d) In the long term, investment in human capital and innovation and development activities has a positive effect on the rates of growth of the GDP and productivity.

e) Using more recent unit root tests, it is observed that the rates of growth of output and productivity have a unit root. This result is significant because of its implications from the point of view of economic theory, as well as its implications from the point of view of the specification of the empirical model.

f) It provides evidence of the existence of a long-term positive effect of the real exchange rate, as a measure of competitiveness, on output and productivity. Moreover, this effect can be considered robust, since it is an empirical regularity that is maintained in each of the models analysed.

g) In the analysis by provinces, new evidence is provided of the existence of divergence during the pre-reform (1952-1978) and convergence in the post-reform period (1978-2005), taking into account both the size of the population of each of the provinces analysed and the level of activity. Similarly, after taking the 'neighbour effect' into account for each of the provinces of China, the existence of convergence is still observed.

4. Conclusions Obtained: Future Lines of Research

4.1 Conclusions and Final Comments

The first chapter of my Doctoral Thesis offer empirical evidence to show that both exports and investment have played a significant role in the process of growth in the Chinese economy. Furthermore, from our findings it can also be seen that innovation activities have stimulated investment in the long run. Both results are robust to different specifications.

Nevertheless, without questioning the significant role played by exports and investment, the theory of endogenous growth underlines the role played by imports more than exports in the process of growth of an economy by having access to imported capital and intermediate goods, which are an important source of advanced technology transfer and is crucial mainly in developing countries. In the case of the Chinese economy, importation of capital goods and intermediate goods from countries with an advanced level of technology has played a key role in accelerating and guaranteeing the process of industrialisation. This is the main motive that led us to extend the first chapter to analyse the role of imports in output and productivity in China, and to clarify the direction of the causality between imports and level of activity.

Our results show that imports, like investment, affect the economic development of the Chinese economy, with the presence of what the literature has called an import-led growth effect. This result is robust to different specifications of the model.

Nevertheless, from economic theory, as economists we know that the permanent effect of capital accumulation largely depends on the factors determining it and whether supply factors or demand factors predominate among them. It is a well-known fact that we should only expect positive effects from long-term capital accumulation on output and productivity if supply factors predominate among its determining factors, due to the embodied technological progress that exists in capital accumulation. Based on this premise, the second chapter of my Doctoral Thesis includes an examination of equipment investment, as one of the components of capital accumulation. It also incorporates other growth factors highlighted in the literature, such as infrastructures, exports, human capital and innovation activities. Our results suggest that both equipment and exports are significant factors when it comes to explaining long-term output and productivity in China, even while controlling for other sources of growth in the period under consideration. We also found that the causality runs in just one direction, i.e. from investment in equipment and exports to output and labour productivity. When infrastructures and human capital were introduced into the model, our results showed that they are also significant factors in the long-term dynamics of labour productivity and output. As in previous cases, the effect of investment in equipment on the level of activity is robust to different specifications of the model. This approach, although not decisive, endorses the existence of a way of incorporating technological improvements through investment, which, together with the positive effect of human capital on output and productivity and R&D, would be coherent with the hypothesis that these factors have played an important role in the growth process. In fact our results would be in line with the models that integrate Schumpeter-like and Solow-Swan-type models, such as the ones developed by Aghion and Howitt (1998).

In Chapter 3, the main aim of this work was to ascertain the significance of the endogenous growth models in explaining the economic growth of China from 1965 to 2000, both for the consequences that this type of model has on economic policy and for their empirical importance. More particularly, the properties of the time series of the rates of growth of the GDP and labour productivity were explored. The role played by both the accumulation of physical and human capital and their interaction with other sources of economic growth, such as opening up to trade, spending on R&D and competitiveness in the short and long run were also investigated. Furthermore, in order to examine the robustness of our results, three alternative trade measures (export-to-GDP, imports-to-GDP and trade-to-GDP ratios) were also considered.

From our findings it can be seen that, first, output and productivity growth rates are not stationary, that is to say, they display persistent movements. The results also indicate that the rate of capital accumulation (understood in the widest sense of the term, including both physical and human capital) is one of the most important sources of growth in the Chinese economy. Additionally, in accordance with the different extensions of the endogenous growth models, it was found that the level of resources incorporated into the R&D activities and openness to trade (regardless of the measure used: trade, exports or imports) have a positive influence on the rates of growth of output and labour productivity in the long run. Lastly, evidence was found to support the idea that maintaining a 'competitive' real exchange rate has also played an important role in explaining the rates of growth of output and labour productivity in the period under consideration. These findings, taken as a whole, allow us to state that the process of growth undergone by the Chinese economy is not only the result of a process of accumulating factors, but that this accumulation of factors has coexisted with a significant increase in efficiency in the long run. Hence, although it is difficult to draw a strict distinction between the different models of growth, the results seem to be more coherent with the implications of certain versions of the two endogenous growth models than with the Solow-type growth models.

The last chapter of my Doctoral Thesis examines whether the regional differences in terms of per capita income tend to disappear or, conversely, said differences are persistent throughout the period analysed (1952-2005). From our results, it would seem that there are two different components in the period under study. From 1952 to 1978 there is a clear tendency for the provinces to be among the lowest income states, while the opposite occurred in the post-reform period. These findings are confirmed and indeed stressed even more if we take into account both the population of each province and its level of activity in the process of convergence in terms of per capita income. Although the pattern that is found is convergence, it coexists throughout the whole of the period with small clusters that behave differently to the average of the rest of the provinces in China. Finally, when aspects related with geographic location are taken into account, our results show a certain degree of convergence among clusters, which seems to indicate that the spatial externalities are significant in the convergence of the provinces of China, although the clear-cut bi-modality persists throughout the period under study. These findings are relevant because of their implications in regional economic policymaking.

Although from in terms of increasing its rate of economic growth, the economic development strategy followed by the Chinese authorities has been a success, there are deep structural problems that can be a source of limitations (and even more so in the future), which means our conclusions need qualifying. First, the remarkable process of growth has to be translated into improvements in the distribution of incomes and economic well-being among the population. These objectives are incompatible with the strategy maintained throughout most of the period under consideration by which the coastal and urban areas were improved at the expense of rural zones (thus increasing inequality among inter-regional incomes). They are also incompatible with the political option of laying emphasis on the weight of investment to the detriment of consumption in the composition of the GDP.

Second, although evidence was found to support the notion that physical capital is a source of growth in China in the long term, it is doubtful whether the high rates of saving and investment can be sustained, not only because this strategy has significant costs in terms of low levels of consumption, but because it could affect productivity of capital and the efficiency of investment in the future. Thus, despite its positive effect on the rate of growth, it does not seem feasible to leave the growth of China in the hands of just increases in rates of savings and investment, and even less so when these rates could even drop sometime in the future. Thus, this scenario will affect the rhythm of technological innovation that has been incorporated into the installed capital stock and may weaken the forces that offset the tendency of returns on capital accumulation to diminish. However, as we see things, there are a number of possible options available to offset this tendency. It is well known that there are important inequalities among the provinces of China and if we examine the regional variation in the capital structure, we can see that it is essentially located in the coastal provinces. Thus, initially, one possible way to allow the above-mentioned investment policy to continue is to redistribute the new investments in the less developed provinces of China. This possibility, however, is not free of risks and difficulties, above all because it would be necessary to invert some of the tendencies resulting from the combination of interventionist policies, together with a greater orientation towards a market economy.

From another point of view, given that we have found that human capital and innovation exert a direct positive influence on economic growth and that these two key factors are relatively scarce in the Chinese economy (both in absolute terms and when compared to developed countries), there is still a considerable amount of leeway for stimulating technological innovation and the accumulation of human capital. At the same time more balanced and sustainable growth is achieved.

Lastly, everything seems to indicate that the different reforms that have been launched to facilitate the integration of China within the international markets and that have turned the Chinese economy into one of the largest traders in the world have been successful. Yet the high rates of investment have intensified its dependence on imported intermediate goods and capital, which, in addition to weakening internal demand, also results in a growing dependence on the exterior. This, in turn, has increased the need for high levels of exports in order to relax the foreign exchange constraints. Up until now this need for high levels of exports does not appear to have been a problem, but some critics believe that keeping up the current rate of growth of exports is unsustainable because it depends on the capacity of foreign demand to absorb Chinese products and this makes the economy more vulnerable to external shocks.

This last consideration may also be affected by the sustainability of exchange rate policy. Hence, although up until now maintaining a competitive exchange rate appears to have stimulated growth, it seems unlikely to continue systematically because of the imbalances that this strategy entails in terms of accumulation of reserves and its implications for monetary policy management.

Although from the results of our regional analysis we can conclude that the tendency during the pre-reform period was towards divergence, in terms of per capita income, while during the post-reform period it was towards convergence, it must be pointed out that these two opposing tendencies have coexisted, with the Chinese provinces clearly stratified in different clubs. This phenomenon is of considerable concern to the Chinese authorities and shows that there is still a certain amount of room for promoting economic policies aimed at stimulating convergence in terms of per capita GDP among the provinces of China, since the natural tendency towards spatial agglomeration seems to continue. Thus, in addition to implementing regional policies and the regional dimensions of other central government policies aimed at balancing regional development (central investment projects, building infrastructures, credit policies, and so forth), other more specific types of measures are also needed to balance the tendency towards agglomeration of economic activity induced by the market forces and to accomplish more balanced and sustainable growth (for example, tending to reconsider interprovincial mobility).

To sum up, although our findings suggest that there are signs of successful progress in the growth of the Chinese economy in the past, with significant gains in efficiency, there are still deep structural problems as well as others generated by the actual growth process itself. Further economic reforms therefore need to be introduced in order to ensure the sustainability of economic growth and development in the future.

4.2 Future Lines of Research

Future lines of research, some of which are already being undertaken, can be divided into two large groups: at national level and at provincial and city level.

a) At national level:

First, because the results of my research indicate that both exports and imports have played a decisive role (albeit by means of different mechanisms) in the growth of the Chinese economy, efforts are being made to make this analysis more detailed by taking into account not only the total amount of imports and exports but also the exports by manufacturers and capital imports. The reason for this is that everything seems to point towards these being the real driving forces behind the growth of the Chinese economy over the last four decades.

Second, because we have found a regular relation between the real exchange rate and its effect on output and productivity, studies are going to be conducted to examine the imbalances between the real exchange rate of the Yuan and different currencies by using different approaches reported in the literature. We believe this point is very important both for the Chinese economy and for the rest of the world, as shown by the current economic crisis and the possible strategies that can be used to get over it.[2]

a) At the Spatial level:

The first line of work in the spatial analysis (and in which the data is broken down in much greater detail) is to analyse the convergence or divergence of the Chinese economy in terms of per capita income in the different provinces. The aim is to continue to examine in greater depth the income differentials observed among Chinese provinces. Following Quah's (1993) non-parametric methodology, we analysed the convergence of Chinese regions and the formation of regional clusters using only per capita income. From our results we concluded that during the pre-reform period (1952-1978) per capita income in the Chinese provinces tended to diverge whereas during the post-reform period (1978-2005) the opposite effect is observed; in other words, the poorest provinces tended to grow faster than the rich ones, which led to a convergence effect among the different regions. Nevertheless, what we expect to analyse next is whether that convergence is produced due to gains in productivity or because of increases in capital intensity. This analysis is going to be carried out using both Kernel density distributions

[2] See, in this vein, the recent opinions of Blanchard in Finances and Development (September, 2009). IMF

and the efficiency and productivity indices proposed by Kumar and Rusell (2002). This point is crucial to be able to understand the sustainability of regional growth in the Chinese economy.

The second line of work is based on extending the previous analysis of convergence to determine whether each of the Chinese provinces converge, diverge or are catching up with respect to the national average for China or, conversely, there are small regional clusters. Said analysis will be conducted within a context of analyses of time series from 1952 to 2007. The advantage of this approach with respect to the previous one lies in the fact that it is able to determine the behaviour of each province with respect to the Chinese national average or with respect to the clusters that were found. It therefore provides useful information for developing specific economic policies for stimulating a particular region.

In the third line of research, the aim is to analyse aspects related with the geography and location of the different Chinese provinces in greater detail. Hence, first of all we are developing an indicator of the *Market Potential* of each of the provinces in China between 1952 and 2007. Later, we will carry out an empirical application using the methodology from the panel data in order to investigate the factors that potentially determine regional growth in China, taking both the location aspect and the heterogeneity of the Chinese provinces into account.

Chapter I

The Chinese Economic Growth: A Reappraisal

1.1 Introduction

The Chinese economy has been undergoing a spectacular growth process for almost four decades. China's GDP showed an average growth rate of around eight percent over the period 1963-1978, in spite of the negative effects derived from the Great Leap Forward and the Cultural Revolution. Furthermore, this growth accelerated even further from the end of the 1970s until 2004, when the annual average growth rate reached more than nine percent, and exceeded 10 percent in 2005. This evolution, which currently has no parallel with other economies, and probably has not had in the past, has helped increase the Chinese contribution to the world GDP. Thus, the percentage of the Chinese contribution to the world GDP rose from less than one percent at the beginning of the 1960s to five percent in the middle of the 2000s.

One of the main factors responsible for this economic growth has probably been China's high rates of domestic saving and investment since the 1950s and 1960s, when the average ratio of investment over the GDP was around 20 percent, and has intensified in recent decades with investment values of over 40 percent of the GDP in 2004. However, China embarked on an ambitious program of economic reforms in 1978. These reforms, including the progressive adoption of market-oriented and open-door strategies for development that culminated in 2001 with its adhesion to the WTO, have led to an impressive export performance, increasing the Chinese participation in the world export markets from negligible values to more than seven percent in 2005. At the same time they have sparked the debate about their role in China's economic growth.

The literature on economic growth has revealed that a wide variety of factors could help to explain output and productivity growth in the long run. Investment in equipment, infrastructures or R&D, besides other more institutional factors (such as openness, improvement in education, regulation changes, property rights, mechanisms of allocation, etc.), are the main candidates to account for the dynamics in the levels of activity and productivity observed in most economies. Of these factors, we decided to focus on the two which have apparently been in the mainstream of the explanation of Chinese economic growth in the last few decades, namely, capital accumulation and openness, especially with regard to exports. Nevertheless, many researchers have questioned whether these factors really have long-run effects on growth and productivity and even the direction of the causality among these variables. Thus, very little agreement exists about the preponderance of the different factors in these processes. Specifically, even the influence that China's capital accumulation process has had on long-run growth has been questioned insofar as the enormous investment effort that was made did not seem to follow or lead to an appreciable improvement in productivity (Chow, 1993; De Long and Summers, 1991 and 1992). The question would be of no greater significance if it were not for the foreseeable differences in relation to the long-run sustainability of growth and its implications on economic policy[3]. Have Chinese policies to promote domestic saving at the expense of consumption contributed from the point of view of long-run growth? Has capital accumulation given rise to permanent increases in productivity, that is, improved efficiency of workers? Is the adoption or the maintenance of almost mercantilist export programs really a suitable strategy in China? Is there any evidence of complementarity between the different sources of growth considered to date, or are there periods of a certain degree of alternation? The role played by capital

[3] A discussion of the need for rebalance of the source of economic growth in China can be found in Prasad and Rajan (2006).

accumulation and exports on economic growth thus continues to be one of the missing pieces preventing us from understanding the recent Chinese economic development.

Therefore, explaining whether the sharp economic growth that the Chinese economy has experienced has been caused only by high domestic saving and investment rates and the consequent capital accumulation or whether, on the contrary, there is another case of export-led growth due to the open-door policy proves to be an interesting question from both an academic point of view and a perspective that is strictly related to the evaluation and decision-making of economic policy. The core issue is a reappraisal of the controversy that appeared in the mid-1990s in relation to the sources of economic growth in high-performing Asian economies (Pack and Page, 1994, and Young, 1992 and 1994). However, the Chinese development process has had its own singular characteristics, and we have to account for them properly in order to understand the implications of these reforms. To do so, it is necessary to go back some years in time. Even though the reforms introduced during the Maoist era were not void of certain deficiencies, they did play an important role and provided a foundation for economic growth in the transition era, especially in terms of investment in transport systems, infrastructures, and technical improvements in agriculture. China's investment policy oriented toward the main strategic sectors, its market-oriented and open-door strategies, together with its high degree of government intervention in the domestic economy, created a combination of development policies to enhance rapid and successful growth. In this context, the purpose of this paper is to analyze the relationship between different sources of growth, especially investment and exports, and their role in explaining the long-run steady state and the short-run dynamics of output and labor productivity in China from the early 1960s up to 2004.

Although policy interventions and institutional changes have been continuous and characteristic of China throughout the period under study, the investment effort was important and sustained in both pre- and post-reform periods, and probably represents the link that allowed continuity between the two periods in the Chinese growth strategy. Nevertheless, besides this investor effort, other factors have probably contributed to create the initial conditions required for the success of these gradualist reforms. First, there are the changes produced in the composition of the industrial sector since the 1950s, as a consequence of changes in the industrial development strategy that was pursued. Thus, heavy industry contributed 13 percent of industrial output in 1952. This percentage reached a figure of 33 percent in 1965, and 42 percent at the beginning of the reforms. In contrast, light industry, which contributed 52 percent in 1952, dropped to 30 percent in 1965 and to 20 percent in 1978 (Bramall, 2000, p. 149). Second, we can consider the high level of education compared with LDCs (Nolan, 1995), which could probably be accounted for by the program of mass secondary education initiated in 1955 and which favored industrialization in rural areas (Pepper, 1996). Third, other important factors were the absence of severe crises, macroeconomic stability and a reduced external debt when the reforms began (Bramall, 2000; Rodrik, 1996; Lardy, 1995). And finally, a high degree of decentralization of government that favored the gradual application of economic reforms (Bramall, 2000). Without these initial conditions that differentiate China from other growth experiences in regions like East European and South American countries or Russia, it would probably be impossible to understand how this large amount of capital accumulation and the exceptional export performance have contributed to stimulate growth over the last four decades.

We jointly analyze the role that investment and exports, along with other factors such as research and development (R&D) expenditure, play as determinants that boost economic growth in China. Furthermore, our paper attempts to clarify some aspects of the discussion related to the relevance of productivity gains and technological progress in this process. However, since the interaction that exists between a large economy, such as that of China, and the rest of the world is known, we have included other variables in our analysis, such as the real exchange rate and the US activity level[4]. A cointegrated VAR model is fitted to this set of variables. This methodology enabled us to perform a joint modeling in a context in which our variables are closely related to each other, and there may be problems of endogeneity. Furthermore, to

[4] A justification for the inclusion of this kind of control variable in a similar context to this paper can be seen in Marin (1992). Moreover, US GDP is usually employed as a reference country of world activity.

consider the existence of structural changes in our relations and to guarantee the stability of the parameters we allowed structural breaks in the estimated models. The econometric results provide evidence that both exports and investment (in physical capital and R&D) are the main factors that determine the level of labor productivity and output in the long run. Moreover, improvements in competitiveness, namely, the real exchange rate depreciation is also significant in explaining output in the long run.

The paper is arranged as follows. In the next section we review the literature to see how exports and capital accumulation encourage output and productivity. In the third section we define the variables and present the econometric methodology. The empirical analysis is included in the fourth section. Finally, some concluding comments are provided in the fifth section.

1.2 Overview of the literature

The conventional Solow-Saw textbook growth model suggests that capital accumulation plays a minor role in long-run economic growth. Of course, these models show that those countries which invest more tend to grow more. However, this effect seems to be transitory and could disappear in the absence of other factors that stimulate steady-state growth. In other words, without technological progress, which is widely understood as improved technical skills and management that allow sustained increases in the productivity of these production factors, the effect of an increase in capital accumulation would be that the country would have a greater income per capita, and that economic growth would have stabilized to "normal" rates after a certain period of time. From this perspective, investment could not be considered a source of sustained economic growth. This belief is also supported by R&D-based endogenous growth models[5]. However, De Long and Summers (1991 and 1992) argue that investment in equipment is apparently associated with higher growth, due to the embodied technological progress, and the positive role of government infrastructure investment in improving economic activity and

[5] See Romer (1986, 1987, 1990), Lucas (1988), Barro (1991) and Grossman and Helpman (1991), among others.

productivity[6] is well known. These findings are more consistent with the main implications of other types of endogenous growth models, such as the AK or Schumpeterian models[7]. Unlike the R&D-based models, the AK model implies that long-run growth and productivity levels depend on capital accumulation, among other factors. The same implication is also supported by the Schumpeterian models. Furthermore, in this kind of models, "capital and knowledge are two state variables determining the level of output at any point of time" and "capital accumulation and innovation should be complementary processes, both playing a critical role"[8]. In this sense, both investments in equipment and R&D expenditure can interact to reinforce this relationship. It is relevant that this complementary relationship is mainly supported by the existence of the technological progress embodied in investment in equipment.

Thus, from a theoretical point of view, capital accumulation is not free of a certain amount of ambiguity as regards its relationship with the GDP or labor productivity. Neither is there much more agreement from the empirical point of view. For example, Jones (1995) concludes that AK growth models do not provide a good description of growth in 15 selected OECD countries, while Blomstrom et al. (1996) found that causality runs from economic growth to investment[9]. Nevertheless, the opposite view may also be found in the empirical literature. For example, recently Bond et al. (2004), in pooled annual data for 98 countries over the period 1960-98, found evidence that an increase in investment as a share of the GDP predicts a higher growth rate of output per worker. More specifically, following Madsen (2002), if capital investment is driven fundamentally by supply-side factors (such as the embodied technological progress), investment is expected to determine output. In contrast, if demand factors predominate among the determinants of investment, we expect to find causality relations running from output to investment.

There is little empirical evidence in the literature of the investment-led growth effect in China. However, any evidence to this effect does seem to recognize that capital accumulation

[6] See Aschauer (1988 and 1989).

[7] See for example, Rebelo (1991) and Howitt (2000).

[8] Howitt and Aghion (1998), p.112.

[9] A review of the recent empirical literature can be seen in Easterly and Levine (2001).

has played an important role in the process of economic growth (Kwan et al., 1999)[10]. There is less agreement, however, on the role of capital accumulation as a source of technological progress and productivity improvement. For example, Chow (1993) emphasized the role of capital accumulation as the main source of Chinese economic growth from the 1950s until the end of the 1980s. Still, there was no evidence of technological progress during this period[11]. Nonetheless, Yusuf (1994) argued that not only was capital accumulation an important determinant of economic growth, but that technological progress also played a significant role from 1978 to 1993[12]. Even more, some authors like Hu and Khan (1996) or Caruso (2002), argued that although the productivity growth has risen sharply during the early years of the reform, during the pre-reform period was also positive, in contrast with Chow's view. Finally, unlike previous studies, Qin et al. (2005) recently found some evidence that output drives investment in the Chinese economy.

The evidence found in the literature suggests that capital accumulation has been an important factor in China's successful growth. However, there is some debate about whether capital accumulation is the only factor explaining the high growth rates in China (as in other planned economies that experienced rapid growth through capital accumulation) or whether other additional factors, for example exports, intervene together with capital accumulation, which could help explain the dynamics of the Chinese performance.[13]

Openness, especially the expansion of exports, has also been considered to be one of the key factors to promote economic growth in developed and developing countries[14]. Among the channels identified in the literature as potential generators of positive effects on output and productivity, the most immediate is the possibility that exposure to trade will induce a self-

[10] Kwan et al. (1999) found empirical evidence that investment influences positively growth during the period 1953-1993.
[11] Similar results are possible to find in Chow and Lin (2002) and Chow (2008)
[12] In addition, Wu (2000) found evidence that investment has been an important stimulus during the post-reform period for TFP in Fujian, Guangdong, Taiwan and Hong Kong.
[13] In this paper, we focus on the role of exports on economic development in China, although there are additional factors that account for the dynamics of output and productivity like imports, institutions, the allocation of economic resources etc. In the appendix 1B is examined the role played by imports on China's growth as an additional factor of growth.
[14] A recent survey can be seen in Lopez (2005).

selection of the firms (Melitz, 2003), the most productive being the ones that finally become exporters and therefore have a positive effect on the aggregate productivity[15]. In addition, access to foreign markets positively affects productivity in the presence of economies of scale[16]. However, the literature on this question emphasizes the existence of positive spillovers associated with the exporting activity. Several channels exist in which these spillovers can affect productivity. The interaction with firms from others countries and increased competition tend to improve the competitiveness of the firms operating in the exporting sector. Moreover, there is a learning-by-exporting effect that tends to generate productivity and enhances the effects among exporting firms[17], which can in turn generate positive externalities in the rest of the economy, since more efficient management and organizational styles, labor training and improved production techniques are adopted[18]. Finally, the exporting activity allows foreign exchange constraints to be relaxed, thus permitting increased imports of capital and intermediate goods[19].

Nevertheless, despite these arguments, there is some skepticism about the ability of openness to explain the success in foreign markets and productivity gains, or about exporting firms' being more productive than non-exporters[20]. We even found evidence for the existence of a growth-driven exports hypothesis[21], according to which countries with higher incomes engage in more trade, i.e. Helpman (1988). In fact, the endogeneity problem of trade has been a recurrent aspect in the empirical literature on openness and growth[22], and there are no conclusive results, especially in the time series analysis[23].

The evidence found in the Chinese economy is in agreement with the rest of the empirical literature. Shan and Sun (1998) offer a wide selection of empirical studies on the export-led growth hypothesis, and all papers seem to support the hypothesis. However, their results

[15] This aspect was studied empirically by Bernard and Jensen (1999) for the USA and empirical evidence was later collected for different countries. A review of empirical literature can be found in Lopez (2005).
[16] Helpman and Krugman (1985).
[17] See Young (1991), Chuang (1998), Clerides et al. (1998) and Aw et al. (2000).
[18] Feder (1983).
[19] See Esfahani, H.S. (1991) and Riezman et al. (1996).
[20] See for example Rodrik (1999), Panagariya (2000) or Rodriguez and Rodrik (2001).
[21] For example, in Kunst and Marin (1989) and Love and Chandra (2005) there is evidence that the causality runs from productivity or from output to exports.
[22] See for example Frankel and Romer (1999), Irwin and Terviö (2002) and Noguer and Siscart (2005).
[23] See for example the comments and references in Giles and Williams (2000) or Cuadros et al. (2004).

indicate that bidirectional causality exists between exports and output in China. The positive effect of exports on output is also found in Liu et al. (1997, 2002), Lin (1999), Jin (2004) and Yao (2006) but with different specifications[24]. Finally, in a recent paper, and contrary to the general perception, Hsiao and Hsiao (2006) found that exports do not cause China's GDP. Thus, the current empirical literature on the role that exports play in the Chinese economic development seems inconclusive.

Regardless of the controversial aspect of the direction in which causality runs between investment and output, an investment-led growth in China should be reconciled with the spectacular growth of Chinese exports. This possibility was underlined by Rodrik (1995) when explaining the economic growths of Korea and Taiwan in the 1960s. According to Rodrik, the outward orientation of these economies was more the result of the investment boom than the consequence of an export-led growth effect. The increase in exports was the result of export-oriented policies that enabled the increase in demand for imported capital goods (a consequence of the investment boom) to be met. However, as Baldwin and Seghezza (1996) argue, the opposite point of view is also feasible. According to these authors trade-induced investment-led growth could have taken place and, in line with our results, there is evidence that both exports and investment are determinants that boost output growth (Yu, 1998, and Kwan et al., 1999).

The question is not whether permanent productivity shocks need to exist in order to guarantee sustained growth in the long run, but rather what factors can be the cause of these shocks. Nobody questions the fact that the accumulation of productive factors, especially capital accumulation, has positive effects on output and productivity in the short run. The question is whether that effect is permanent, in other words, if it affects both variables in their long-run steady state. Our objective is not to test alternative specifications of the relationship between the accumulation of productive factors and other sources of economic growth, as found in the empirical literature on economic growth[25]. Indeed, our objective is something more basic: to

[24] Chuang (2000) find a positive relationship between exports and growth in Taiwan over the period 1952-1995.

[25] See, for example, De Long and Summers (1991 and 1992), Jones (1995) or Easterly and Levine (2001).

detect the regularities and interactions between the different sources of growth, and to identify the direction of the causality in the singular process of Chinese economic growth. Thus, our analysis consists in a previous step to consistently explain this process, which is an additional piece in the puzzle that politicians and economists attempt to solve.

In short, there are good reasons to believe that we are in the presence of magnitudes with a high degree of interdependence, and therefore assuming the hypothesis of exogeneity for one variable, or more, could be a risky procedure prior to starting the analysis. This characteristic of the problem that we wish to undertake imposes methodological restrictions. It is preferable to initiate the empirical analysis with a general and the least possible conditional assumptions, thus allowing the data to reveal the nature of the interactions among them. From these relationships, it is possible to advance with the hypothesis about the nature and causes of the forces that have stimulated the rapid economic growth in China in recent decades.

1.3 Econometric Methodology and Data

Our empirical analysis basically uses annual data for China for the period 1964-2004 provided by the NBS of China[26], which has recently published the latest compilation of figures for the Chinese economy in 2004. Our dataset consists of the GDP *(lgdp),* labor productivity – output per worker – *(lprod),* investment *(linv)*[27] , exports in FOB terms *(lexp),* R&D expenditure *(lrd)* of the Chinese economy, the US GDP[28] *(lgdpusa)* and the real exchange rate *(lrer)*. All variables are in logs and real terms, and have been deflated by the GDP deflator. The real exchange rate was calculated using the nominal exchange rate between the Chinese currency and the US dollar (Renminbi/$) and the consumer price indices (CPIs).

---

[26] China Compendium of Statistics 1949-2004. National Bureau of Statistics of China (NBS). Base year 1952=100. We have used the original base year derived from the NBS.

[27] Two types of investment variables are available in China: Gross Fixed Capital Formation, as it is common in the majority of National Accounts, and Fixed Assets. According to the OECD Manual published in 2001 on capital stock measures, the most accurate definition in China is Fixed Assets. However, this variable is limited, so we have used the Gross Fixed Capital Formation in our analysis. In future research, we will attempt to use fixed assets. For further details on the physical capital measure, see Holz (2006).

[28] Data from the USA were taken from the Bureau of Labor Statistics and Bureau of Economic Analysis.

Although data are available from China since 1952, we preferred to move the beginning of the effective sample to 1964, given the difficulty involved in performing a sufficiently homogenous treatment over such a turbulent period as the one between 1958 and 1962, with the Great Leap Forward and the consequent economic collapse that produced abnormally low values of macroeconomic aggregates for the period 1961-1963[29]. However, it is well known that the period under study is not free of shocks, and this led us to use different level-shift dummies to consider the possibility of structural breaks, especially in 1978 or during the 1990s, in the empirical analysis

An analysis of the stationary properties of our variables can be seen in the Appendix 1A. It is possible to see from the unit root test (Phillips Perron and Aumented Dickey Fuller) that all the variables that we considered are $I(1)$ in levels and we reject the possibility of their being $I(2)$.

The methodology that we have used is the cointegrated vector autoregressive (VAR) model proposed by Johansen (1988 and 1995) and Johansen and Juselius (1990 and 1994)[30]. We start the analysis with a broad general specification in which certain restrictions will be imposed until the most irreducible form is reached. We consider that this methodology is appropriate given the potential interdependence between the different variables considered, which suggest that joint modeling should be used to avoid spurious results. In addition this methodology allows a distinction to be drawn between the short-run and long-run relationships between them.

More specifically, we start with an unrestricted VAR model, a restricted linear trend in the cointegration space, and an unrestricted constant (μ) of dimension *r x* 1:

$$\Delta X_t = \alpha\tilde{\beta}_i' \begin{pmatrix} X \\ Z \\ t \\ D_s \end{pmatrix}_{t-1} + \sum_{i=1}^{k-1}\Gamma_i \Delta X_{t-i} + \omega\Delta Z_t + \sum_{i=1}^{k-1}\omega_i \Delta Z_{t-i} + \theta\Delta D_{st} + \sum_{i=1}^{k-1}\theta_i \Delta D_{st-i} + \varphi D_t + \mu + \varepsilon_t \qquad (1)$$

$$\varepsilon_t \sim NIID(0,\Omega) \quad t = 1....T$$

[29] See Chow (1993).
[30] This methodology is based on the principle of "general to specific" discussed in Juselius (1992) and in Hendry and Mizon (1993).

where $\alpha\tilde{\beta}_i$ are the coefficients of the long-run matrix, α gives the direction and speed of adjustment toward equilibrium, and $\tilde{\beta}_i$ are the coefficients of the cointegrated vectors; X is the matrix of endogenous variables in the model, Z is the matrix of weakly exogenous variables, t is the linear trend restricted to the cointegration space, and D_{st} is the matrix of the level-shift dummy. Γ_i is the unrestricted matrix of the coefficients of the short run and of dimension $p \times p$, while ω_i and θ_i are the coefficients of the variables that have been considered prior to analyzing the weakly exogenous variables (Z_t) and the level-shift dummy (D_{st}), respectively. Finally, the term (φD_t) contains a vector of unrestricted dummy variables and their corresponding coefficients. In addition, we assumed that the error term, ε_t, is an i.i.d. Gaussian sequence $N(0, \Omega)$ and the initial values, $X_{-k+1},\ldots X_0$, are fixed. Since the cointegration property is invariant to the incorporation of additional variables in the model, we followed the procedure suggested by Juselius (2007) by sequentially introducing some variables into the model because, according to this author, this process greatly facilitates the identification of the long-run structure in the simple model. In particular, we will begin our analysis with five variables, i.e. productivity or GDP, real exchange rate, exports, investment, and the US GDP, and we will obtain the long-run relationships. Once the simple analysis[31] of the model has been completed, we will include R&D spending, because it potentially maintains a close relationship with investment and output.

1.4 Empirical Analysis

1.4.1 Deterministic Components

In our analysis we have considered a restricted linear trend in the cointegration space because our variables show a linear trend over the period analyzed, which is difficult to justify from an economic point of view. From an empirical point of view, however, the deterministic linear trend could be an alternative to the stochastic trend (Nielsen and Christensen, 2005).

The VAR model assumes that residuals are not autocorrelated and are distributed normally. In order to satisfy the assumptions of the VAR model in our analysis, we included an

[31] We do not report the results for the simple model

unrestricted permanent dummy variable[32], D_{89p}, and two level-shift dummies restricted to the cointegration spaces D_{s78} and D_{s94}. The dummy D_{89p} attempts to capture the political instabilities and economic restrictions in 1989 (restrictive fiscal and monetary policies were introduced by the Chinese government at the end of 1988 to stem sharply rising inflation, the contractive effects of which coincided with the events that took place in *Tiananmen Square*)[33]. A graphical inspection of the residuals, based on the unrestricted VAR (2) model for the Chinese economy, shows that the events which happened in 1989 had a strong impact on the gross fixed capital formation and caused a fall of around 14 percent, as a result of the restrictions on investment and trade made by the government. Moreover, and regardless of the extent of the formal restrictions, the events that took place in 1989 raised doubts about the long-term stability of the Chinese economy and, therefore, adversely affected the expectations of Western (and Hong-Kong) companies. As a result, China suffered a significant loss of trade and investment in the late 1980s (Bramall, 2000).

On the other hand, the justification for the level-shift dummies is immediately apparent. The 1978 dummy is related to the beginning of the political and economic reform process, initiated after the Cultural Revolution[34], whereas the 1994 dummy mainly corresponds to the unification of the dual exchange rate that is still in existence[35]. Furthermore, the liberalization of price controls, which also took place in that year, favored the efficiency of the allocation mechanism in the Chinese economy. Another important event was the fiscal reform in 1994, which enhanced the efficiency of the whole fiscal system because decentralized decision-making would better suit the preferences of local residents and make the incentives of subnational governments compatible with those of the central government, thus reducing enforcement costs.

---

[32] The criterion to include a dummy was $(|\hat{\varepsilon}_{1,t}| > 3.3\hat{\sigma}_{\varepsilon})$. For futher details of the impact of deterministic components in the VAR Model, see Juselius (2007).

[33] See Yusuf (1994).

[34] Although the Cultural Revolution ended in 1976, the reforms that led the way toward the market-oriented economy did not begin until the end of 1978.

[35] The magnitude and impact of the Chinese exchange rate unification in 1994 is the object of some debate. In this year, the exchange rate depreciated by around 43%. However it is difficult to know the impact of this devaluation, as it is difficult to identify what share of transations were taking place at the market rate (Adams et al., 2006).

1.4.2 Productivity Model

Initially, the endogenous variables considered in the model presented in this section are labor productivity[36], investment, exports, real exchange rate and R&D expenditure. The US activity level was included to capture foreign influence on the Chinese economy, and it has been considered a weakly exogenous variable from the beginning. Starting from a four-equation system (labor productivity, investment, exports and real exchange rate), the exogeneity test suggested that exports could be managed as an exogenous variable[37][38].Therefore, in the resulting three-equation system, R&D expenditure was included as an additional endogenous variable. Under this new specification with four endogenous variables (productivity, investment, real exchange rate, and R&D expenditure) and two exogenous variables (exports and US activity), the exogeneity test was applied to show that R&D expenditure can also be considered an exogenous variable[39]. Finally, the determination of the number of lags, according to the criterion of Hannan and Quinn, indicates that two lags are enough to capture the dynamics effects of the model and to avoid autocorrelation problems[40]. In short, the definitive specification that we have considered is a VAR (2) model with three endogenous variables (productivity, investment and real exchange rate) and three exogenous variables (exports, R&D expenditure and US activity), with their corresponding deterministic components.

We made a battery of misspecification tests for the residuals of the model, where neither autocorrelation nor normality problems exist[41]. Although ARCH effects are not observed in the univariate analysis, a small ARCH effect is detected in the multivariate analysis. Nevertheless, Rahbek et al. (2002) and Juselius (2007) suggested that the statistical inference, in particular the determination of the rank test, in the cointegrated VAR model is robust to a moderate ARCH effect, and that, overall, the model is well behaved.

---

[36] In this model productivity was corrected by applying the methodology suggested by Nielsen (2004).
[37] A similar procedure to that used in this approach as regards choosing the variables can be seen in Juselius and MacDonald (2006).
[38] Exports can be considered exogenous in our model for $r = 1$ and *p-value* 0.90.
[39] Weak exogeneity for R&D expenditure is accepted for $r = 2$ and *p-value* 0.73.
[40] These tests are available upon request from the authors
[41] Available upon request for both models

1.4.2.1 Long-Run Identification

Based on the statistical model, we can obtain the number of long-run relationships (*r*), and the number of common trends (*p* - *r*) by the LR test. Table 2 in the Appendix shows the trace test, where everything seems to indicate that two long-run relationships (*r* = *2*) exist in our model, as well as a common trend. In addition, the inverse root of the characteristic polynomial for this rank is 0.80, less than unity, which therefore shows that our model is stationary.

The following cointegration vectors can be found in the selected model. They are expressed as error correction mechanisms (t-values in brackets):

$$\underset{}{ecm_1 = lprod - \underset{[-4.47]}{0.16linv} - \underset{[-11.77]}{0.29l\exp} - \underset{[-5.97]}{0.17D_{s94}}} \quad (2)$$

$$ecm_2 = linv - \underset{[-5.73]}{0.31lrd} + \underset{[-6.99]}{0.20D_{s78}} - \underset{[-24.73]}{0.08t} \quad (3)$$

The first relationship corresponding to (2) describes how exports and investment both account for the level of productivity in the long run. On the other hand, the second relationship (3) shows that R&D expenditure favors an increase in investment. The coefficients associated with the two relationships are statistically significant and show the expected signs. The restrictions imposed in both cointegration relationships were accepted with a p-value of 0.175. The coefficients of adjustment toward equilibrium are statistically significant and negative, and take a value of -0.36 (-5.55) for the first cointegrated vector and -0.64 (-5.86) for the second. Although complete parameter constancy is difficult to guarantee in a period of such important economic changes, the reduced-form model is stable in the forward and backward analysis[42]. In this sense, our estimates should be considered as average effects throughout the period analyzed. Finally, our model seems reasonably stable according to the usual battery of tests.

Our findings are consistent with an export-led productivity growth effect. The first long-run relation in (2) shows a positive relationship between productivity and exports, where the

[42] Available upon request for both models

causality runs unidirectionally from exports to productivity in the long run. Unlike other studies, we have not found a bidirectional causality relation as exports became exogenous in our analysis. Additionally, not only exports but also investment has a positive effect on productivity. This result is interesting because it shows that both exports and capital accumulation play a central role in the long-run dynamics of productivity in China. Thus, our results are also consistent with the existence of an investment-led productivity growth effect. The second long-run relationship shows that investment and R&D expenditure are cointegrated. An interesting result derived from this analysis is that R&D expenditure affects investment directly and positively with a moderate coefficient, and that it has an indirect effect on productivity through investment.

Additionally, on the one hand, the negative sign of the dummy D_{s94} in ecm_1 shows that labor productivity increased after 1994. As already mentioned, this effect is probably related to the whole set of economic policies made by the Chinese government in that year, i.e., the liberalization of price controls, the fiscal reform and the unification of the dual exchange rate. On the other hand, the positive sign in the dummy variable D_{s78} in ecm_2 means that a long-run relationship without this dummy might overestimate the investment level after 1978. This is made possible by the slight slowdown in the investment growth after 1978 [43] – a slowdown that is probably related to four important factors: the over-investment during the Maoist era; the decrease in the growth rate in two important sectors like construction and transportation; the reallocation of investment from traditional to more dynamic sectors like electronic equipment, plastics, pharmaceutical products and chemicals, among others, led by the government with different economic policies; and, finally, the increase in prices during the reforms, especially in 1988-9, due to the fast rate of economic growth favored that the Chinese government made economic restrictions on investment and trade, as already pointed out. However, even though the investment effort fell slightly in the early years of the reform, investment maintained an

[43] Between 1963 and 1978 the average annual growth rate of investment was 13.65 percent, while between 1979 and 2004 the rate fell to 11.65 percent.

upward trend throughout all the period considered, with spectacular growth rates in comparison to those of other economies.

1.4.2.2 Short-Run Identification

Table 1 represents the dynamics of the short-run structure. Similarly to the long-run identification, the starting point consists of a general model in which the restrictions that are imposed on the coefficients show a sequential form. Then, the variables with non-significant coefficients are eliminated until the most irreducible model is reached. The over-identifying restrictions based on the LR test are accepted with χ^2 (23) = 31.669 (0.1072).

Table 1: Short-run Identification

Model 1: Labor Productivity model				Model 2: GDP model			
	Δlprod	*Δlinv*	*Δlrer*		*Δlgdp*	*Δlinv*	*Δlrer*
$\Delta lprod_{t-1}$	0.34	1.14	-	$\Delta lgdp_{t-1}$	-	-	0.64
	(4.79)	*(7.26)*	-		-	-	*(3.83)*
$\Delta lgdpusa$	0.36	-	-0.65	$\Delta linv_{t-1}$	0.21	0.41	-0.23
	(2.74)	-	*(-3.05)*		*(7.31)*	*(5.33)*	*(-3.18)*
$\Delta gdpusa_{t-1}$	0.50	1.05		$\Delta lrer_{t-1}$	-0.25	-0.48	-
	(3.66)	*(2.99)*			*(-2.80)*	*(-2.14)*	-
$\Delta lexp$	-	-0.18	0.13	$\Delta lexp$	0.07	-	-
	-	*(-3.32)*	*(4.55)*		*(4.08)*	-	-
$\Delta lexp_{t-1}$	-	-	-0.09	$\Delta gdpusa$	-	-0.83	-
	-	-	*(-2.80)*		-	*(-2.78)*	-
Δlrd	0.12	0.40	-	$\Delta gdpusa_{t-1}$	0.54	0.94	-
	(5.64)	*(7.95)*	-		*(4.00)*	*(2.76)*	-
Δlrd_{t-1}	0.07	-	-	Δlrd	0.15	0.35	-
	(2.95)	-	-		*(7.29)*	*(6.92)*	-
Constant	-0.95	0.84	0.43	*Constant*	2.29	3.67	1.03
	(-3.58)	*(1.32)*	*(2.35)*		*(7.87)*	*(5.00)*	*(4.79)*
ΔD_{s94}	0.12	0.20	-	ΔD_{s94}	-	-	0.16
	(6.18)	*(3.95)*	-		-	-	*(-5.84)*
ΔD_{s78}	-0.03	-0.14	-	ΔD_{s78}	-	-	-0.08
	(-2.31)	*(-3.23)*	-		-	-	*(-3.39)*
ΔD_{s78t-1}	-0.03	-0.13	-	ΔD_{s78t-1}	-0.05	-0.11	-
	(-2.33)	*(-3.05)*	-		*(-3.07)*	*(2.64)*	-
dum_{89p}	-0.04	-0.27	-	dum_{89p}	-0.04	-0.27	-
	(-2.46)	*(-6.29)*	-		*(-2.30)*	*(-6.27)*	-
$ecm_{1(t-1)}$	**-0.35**	**-0.31**	**-**	$ecm_{1(t-1)}$	**-0.61**	**-0.65**	**-**
	(-7.11)	*(-2.54)*	-		*(-7.65)*	*(-3.27)*	-
$ecm_{2(t-1)}$	**-0.27**	**-0.81**	**-0.13**	$ecm_{2(t-1)}$	**-0.39**	**-1.02**	**-0.52**
	(-5.18)	*(-6.52)*	*(-2.17)*		*(-5.19)*	*(-5.09)*	*(-4.77)*

Productivity adjusts toward equilibrium with the export- and investment-led productivity relationship (ecm_1) and the investment vector (ecm_2). The alpha coefficients show the speed and direction toward equilibrium. In the labor productivity equation, it can be observed that the adjustment is relatively slow and, approximately every two years, productivity adjusts toward equilibrium and is probably associated with the continuous transformations in the Chinese economy in the period considered. Additionally, in the dynamics of the model we can observe that R&D expenditure has a positive effect on the productivity equation in the short run. This indicates that not only the transfer and absorption of foreign technology through the generation of spillovers from exports favor efficiency and productivity, but that efforts in innovation play a relevant role in improving productivity in the Chinese economy. Moreover, foreign demand, measured by the US activity level, shows procyclic performance, which favors productivity growth. Finally, the productivity lag itself positively affects the productivity equation.

Investment also adjusts toward equilibrium with both vectors found in the long run. The alpha coefficients in the investment equation show that, similarly to the previous equation, adjustment with the first vector is relatively slow. However, the adjustment with the second cointegrated vector (investment vector) shows a reasonably fast adjustment toward equilibrium, i.e. almost every year. Moreover, in its own equation investment shows a minor overreaction, given the negative coefficient in ecm_1. It is difficult to explain the reasons for this effect in a model where the parameters are jointly conditioned to each other and where there is more than one vector. However, the overreaction is compensated by the higher and negative value in ecm_2, and as a consequence this long-run relationship adjusts toward equilibrium. An interesting result in the short run is that investment accelerates as productivity increases, since a positive productivity shock probably attracts investment through the expectations of obtaining future returns. In addition, we observe that both foreign demand and R&D expenditure favor increased investment. Nevertheless, one unexpected result we found is that exports would have a transitory and negative effect on the investment equation.

Finally, the third equation reveals that the real exchange rate is appreciated when investment is over the steady-state (ecm_2). This result is probably explained by the fact that when investment is over its value in the long run, it causes an inflationary effect owing to an increase in the aggregate demand, and to the consequent appreciation of the real exchange rate.

1.4.3 Output Model

Similarly to the previous model, our starting point is a simple output model which contains the following variables: Chinese activity level (GDP), exports, investment, real exchange rate and the US activity level. Once the cointegration relationships of this new model have been found, the R&D variable will be included, and the same model specification is maintained.

Once more, either the exogeneity or endogeneity of the variables considered in the simple model is analyzed under the assumption that the US activity level is weakly exogenous. Like the productivity model, the exogeneity test shows us that exports are exogenous with a *p-value* of 0.27. Therefore, by following the same sequence as the previous model specification, we also found that R&D expenditure is exogenous with a *p-value* of 0.09. Thus, at the end of this process, our model contains three endogenous variables (China's GDP, investment, and real exchange rate) and three exogenous variables (exports, R&D expenditure and the US activity level). Finally, the determination of the number of lags in accordance with the criterion of Hannan and Quinn shows that two lags are enough to capture the dynamics effects and to avoid autocorrelation problems.

We also made a battery of misspecification tests for the residuals of this model, where neither autocorrelation nor normality problems were found. Similarly to the productivity model, a slight ARCH effect is observed in the multivariate analysis. Nevertheless, the model is well behaved (Rahbek et al., 2002; Juselius, 2007).

1.4.3.1 Long-Run Identification

In the Appendix 1A it can be seen that both the null hypotheses of the absence of cointegration and the existence of one cointegration vector are clearly rejected. In our model, therefore, we accepted the null hypothesis of the existence of two long-run relationships ($r = 2$), and a common trend, where both p-values accept the null hypothesis, and the inverse roots of the characteristic polynomial for $r = 2$ is 0.78 less than unity. This shows that our relationships are stationary and adjust toward equilibrium.

In the model we selected, the following cointegrating vectors can be found to be expressed as error correction mechanisms (t-values in brackets):

$$ecm_1 = \lg dp - 0.39linv - 0.88lrer - 0.10l\exp - 0.25D_{s94} - 0.15D_{s78}$$

[-9.98] [-6.20] [-3.31] [-6.43] [-4.32] (4)

$$ecm_2 = linv - 0.28lrd + 0.23D_{s78} - 0.09t$$

[-5.67] [7.68] [-29.09] (5)

The coefficients associated with the variables in both relations are statistically significant and show the expected signs. The restrictions imposed in both cointegrating vectors are accepted with a *p-value* of 0.425. The adjustment coefficients toward equilibrium are also statistically significant and negative, and show a value of -0.42 (-7.21) and -0.82(-6.47) for the first and second relationship, respectively, (ecm_1 and ecm_2). Finally, the reduced-form model is stable in the forward and backward analysis. Like the previous model, however, complete parameter constancy is difficult to guarantee, and our estimates should be considered to be average effects.

The long-run model for output is very similar to the model of productivity that we have seen. The first relationship corresponding to (4) shows a positive relationship among China's output, investment, real exchange rate and exports. Our findings are consistent with the export-led growth hypothesis, which predicts that a positive relationship exists between the level of domestic activity and exports, where the direction of the causality runs unidirectionally from exports to the GDP in the long run. Furthermore, the positive effect of investment on output in the long run emphasized by the literature also appears in this relationship. Our findings are therefore consistent with Yusuf (1994), who found that capital accumulation is one of the most important factors in the economic growth process in China.

We included the real exchange rate as a proxy variable to take into account the competitiveness in the analysis, given that a close relationship is maintained between the real exchange rate and exports. On contrasting with the previous productivity model, however, it can be observed that the real exchange rate affects output in the long run.

The effects of R&D expenditure on investment can be observed in the second relationship (5). This result is interesting in the sense that investment is affected by the innovating effort of the Chinese economy in both the models analyzed, as it allows investment to increase and stimulates the accumulation of physical capital, which also favors economic growth.

The interpretation of the deterministic components is similar to that of the productivity model. In the first relation, however, it is possible to observe that dummy D_{s78} has a positive effect on the real GDP, showing that the output level had increased after that year, as already pointed out.

1.4.3.2 Short-Run Identification

Table 1 shows the dynamic structure of the output model. Similarly to the previous model, we started with a general specification in which restrictions are imposed on the coefficients of the variables analyzed sequentially, and the non-significant variables are eliminated until the most irreducible model is reached. The over-identifying restrictions LR test is accepted and is distributed as χ^2 (25) = 32.606 (0.1412).

The Chinese activity level adjusts toward equilibrium with the two cointegrated vectors found. In contrast to the previous model, the alpha coefficients in this model show a reasonably fast adjustment. Output level adjusts toward equilibrium with the first relation approximately every year and a half. In the dynamic model, the US activity level displays a procyclic performance which is similar to that of the productivity model. Furthermore, R&D expenditure, investment and exports positively affect output in the short run. However, the real exchange rate shows a transitory and negative effect.

Like the productivity model, investment adjusts toward equilibrium with the two vectors found. In this equation, it can be observed how both vectors show a relatively fast speed of adjustment. Investment is error correcting with the second long-run relation and adjusts toward equilibrium approximately every year. Similarly to the productivity model, the investment equation overreacts with the first relation (productivity vector), but is also compensated by the negative coefficient in ecm_2. R&D expenditure, which allows knowledge or innovations to be absorbed, has directly favored increased investment in China, and has also allowed the overall growth rate to accelerate in the last two decades. The dynamics of this model show that investment, R&D expenditure and the US activity level have a positive effect on the investment equation. Once again, however, the real exchange rate has a transitory and negative effect in the short run.

Finally, similar to the previous model, the real exchange rate adjusts toward equilibrium with the second cointegrated vector found (ecm_2). When investment is over its value in the long run, it causes an appreciation of the real exchange rate, and the alpha coefficient shows a reasonable speed of adjustment toward equilibrium, at approximately a year and a half.[44]

1.5 Comments and Conclusions

On the one hand, and from a theoretical point of view, there is no agreement about the effects of the accumulation of capital on the GDP or labor productivity in the long run. Moreover, the empirical literature has also questioned the direction of the causality between investment and output, and the evidence for investment-led growth or reverse causality is ambiguous. On the other hand, openness has been identified as an important additional force behind economic growth. Trade, especially exports, is also considered to be an important channel of positive effects on output and productivity. Economies of scale, self-selection of firms, spillovers or externalities are some of the different arguments which may be found in the

[44] Although the real exchange rate is endogenous in our analysis, we focus in the role played by investment and exports, given that the objective of this paper is not to analyze the determinants of the real exchange rate and it has been included as a control variable.

literature on trade and economic growth. Nevertheless, and despite these arguments, the evidence of the positive effect of trade on growth seems inconclusive.

In this paper, we have analyzed whether the rapid process of economic growth in China since the 1960s, especially in labor productivity and output, can be mainly explained by an investment-led growth effect or, conversely, we are in the presence of an export-led growth effect. Unlike other studies, we included investment and exports in our models, together with other relevant factors such as R&D expenditure, the real exchange rate and foreign output in our analysis. Thus, we emphasized the complementarities between capital accumulation and innovation, combined with openness, as the most important channels to stimulate economic activity.

Our empirical evidence shows that both an export-led growth effect and an investment-led growth effect are relevant in the Chinese economy. And this result remains whether we analyze the long-term dynamics of output or productivity. In both models is found a positive relationship among labor productivity or output, exports and investment in the long run. Additionally, our findings show that exports exogenously drive output and productivity in the long run. Besides we found that R&D encourages investment with a moderate coefficient in the long run. An interesting result in the equilibrium is that exports show a greater effect on productivity than investment, and are likely to be associated with the economies of scale and the positive effects of spillovers from technology transfer, more efficient reallocation of resources, and competitiveness in the international market. In contrast to the productivity model, we found that the real exchange rate played an important role in determining the output level. Moreover, bearing in mind the continuous process of reforms in China during the period under study, these findings can only be found if structural changes in 1978 and 1994 are considered.

In the dynamics we found common positive effects of the productivity lag, the US GDP lag and the effect of R&D on the productivity and investment equations in the short run. Conversely, in the dynamics of the output model, we found that the US GDP, exports and R&D positively and regularly affect the output equation, but only US GDP and R&D have a positive effect on the investment equation in the short run. In contrast, in this model, the real exchange rate has a negative and transitory effect in both the aforementioned equations.

Our findings are interesting in the sense that trade, exports, and investment all promote productivity and output, which suggests that trade- and investment-oriented policies have played a relevant role in the Chinese economic growth process. However, exports seem to stimulate productivity more than output, thus reinforcing the role of openness as a source of technological progress. Additionally, we found that R&D favored an increase in investment in all the models. Jointly, these effects seem consistent with the implications of certain endogenous growth models, such as the AK models or with a Shumpeterian version of endogenous growth. In these kinds of models, a close relationship remains between investment and technological progress, since capital formation remains obsolete in the absence of technological progress and it would have no effect on economic growth in the long run (Howitt, 2000). New technological advances require an investment that enables them to be incorporated into the productive process and which favors the output growth in the long run. Additionally, R&D expenditure, which allows knowledge or innovations to be absorbed, has directly favored increased investment in China, and has also allowed the overall growth rate to accelerate in the last two decades.

Although our empirical analysis cannot determine whether the positive effect of investment on output and productivity is caused by an increase in capital accumulation or by improvements in productivity, or both, we can hypothesize that both channels are relevant. The first reason is because the existence of a positive and stable relationship in the long run between these variables is more consistent with the existence of a positive effect on technical progress. The second is that there is a positive correlation between capital accumulation and innovation. And the third reason is that throughout the period considered labor productivity has grown at almost the same rate as the capital/labor ratio[45], which leaves room for increases in total factor productivity[46].

[45] For further details, see Wu (2004).

[46] Looking at a simple Cobb-Douglas production function, the increase in the capital/labor ratio always generate an increase in the labor productivity that is less than proportional, and the magnitud will depend

Finally, if we look at investment and export growth rates and their shares of the GDP, two clear sub-periods can be observed within the period considered. Investment grew faster than exports from 1962 to the end of the 1970s, and the reverse is true since then up to the present day. Thus, the exports-to-GDP ratio clearly increases in the second period considered, from the end of the 1970s until now, while the investment-to-GDP ratio increases over the two periods. This suggests that investment has been a permanent source of growth throughout the four decades analyzed while, as a source of growth, exports appear to be especially relevant only during the post-reform period.

---

on the coefficient of capital.

Appendix 1A

Table 1A.1: Unit Root Tests

	Model 1 (trend & const.)		Model 2 (constant)		Model 3 (none.)	
	PP		PP		PP	
Vbles.	Levels	Diff.	Levels	Diff.	Levels	Diff.
lgdp	-1.75	-5.04*	0.73	-4.77*	22.38	-2.61**
lprod	-0.23	-6.47*	5.47	-4.01*	-3.11*	-3.52*
lexp	-2.31	-5.64*	1.34	-5.41*	6.83	-2.91*
lrer	-1.63	-5.43*	-1.01	-5.47*	1.95	-4.94*
lgdpusa	-4.13**	-4.89*	-1.76	-4.81*	10.50	-1.91***
lrd	-2.39	-6.40*	-0.19	-5.59*	5.25	-4.12*
linv	-3.14	-5.90*	-0.52	-5.82*	10.30	-3.46*

	Model 1 (trend & const.)		Model 2 (constant)		Model 3 (none.)	
	ADF		ADF		ADF	
Vbles.	Levels	Diff.	Levels	Diff.	Levels	Diff.
lgdp	-1.73	-4.44*	0.25	-4.48*	11.01	-2.22**
lprod	-0.56	-4.62*	2.30	-5.35*	-2.69*	-3.48*
lexp	-2.35	-5.67*	1.36	-5.40*	7.15	-3.04*
lrer	-1.46	-5.50*	-1.01	-5.53*	2.09	-4.93*
lgdpusa	-4.93*	-4.90*	-1.39	-4.37*	10.26	-2.17**
lrd	-2.38	-4.60*	-0.43	-4.63	3.05	-4.14*
linv	-4.88*	-4.81*	-0.45	-4.88*	5.87	-3.26*

Note: * Rejection of the null hypothesis at all levels of significance
**Rejection of the null hypothesis at 5% and 10%
*** Rejection of the null hypothesis at 10%

Table 1A.2: Determination of the Rank Test in the Productivity model

p-r	R	E.Value	Trace	Trace*	95%	p-value	p-value*
3	0	0.77	117.85	100.96	77.10	0.000	0.000
2	1	0.59	56.11	49.36	49.6	0.011	0.052
1	2	0.37	19.09	16.55	25.86	**0.254**	**0.415**

Table 1A.3: Determination of the Rank Test in the Output model

p-r	r	E.Value	Trace	Trace*	95%	p-value	p-value*
3	0	0.76	116.82	99.43	76.16	0.000	0.000
2	1	0.59	58.39	50.49	49.62	0.006	0.041
1	2	0.40	20.95	17.02	25.60	**0.166**	**0.375**

Note: (*) corresponds to the trace test with Bartlett's correction. The asymptotic distributions have been simulated for the current deterministic specifications

Appendix 1B

An extension: The Role of Imports in the Chinese Economic Development

In economic terms, the growth of China has been remarkable for almost four decades. Capital accumulation and export promotion policy have been widely analysed in the literature as one of the main sources of this rapid economic growth (Chow, 1993; Siebert, 2007). The Chinese economy, with its singular characteristics, followed the strategy begun by other rapidly developing Asian countries (East Asian Miracle countries) that highlight their rapid export promotion as a central channel enhancing economic growth (World Bank, 1993). However, the endogenous growth literature, in line with the models proposed by Grossman and Helpman (1991), Lee (1995) and Mazumdar (2001), to cite just a few, emphasizes the role played by imports rather than exports in economic growth. In these models, imports (through access to capital goods and intermediate goods from technologically more advanced countries) have become a form of technology transfer and a source of competition that stimulates the domestic industry. Nevertheless, there are other studies, like Rodrik (1995), which suggest that the increase in growth rate in Asian countries was mainly in response to variations in investment, trade being a consequence rather than a cause of rapid economic growth. To the best of our knowledge there is no empirical evidence that analyses the importance of imports as source of long-run growth in China. This extension of our first Chapter attempts to cover this gap in the empirical literature on China's economic growth; that is, its aim is to analyse whether imports also could have played a significant role in boosting productivity and economic development in this country.

China is an interesting case of study because, in spite of the general perception about the decisive role played by exports in the process of growth, in our view, this was not the only factor responsible for its fast growth. Instead, we believe that the promotion of exports, which is beyond question, could have encouraged imports by allowing foreign equipment and intermediate inputs to be acquired from abroad, thus making it an important factor in the growth of China over the last four decades. In fact, some authors, like Shi (1998), argued that the importation of foreign technology has played a key role in the process of industrialization in the

Chinese economy since the fifties. In fact, one of the main objectives of the Chinese government has been to gain access to advanced foreign technology and equipment. This strategy has been a constant throughout the study period (1962-2004), although developed through different stages.

Our dataset is the same that we describe in the main text of this chapter, but now considering imports instead of exports as an additional source of growth in China. In addition, we use the VAR model and we perform all battery of miss-specification tests in these models in a similar way than before until we have the well-specified model. Then, we can test the rank of the long-run matrix. In accordance with the trace test and the roots of the companion matrix, everything seems to indicate that in both the models considered, i.e. the productivity and the output model, there are two long-run relationships.[47] The first economic relation found in each model, we have normalized the long-run relationship in labour productivity and output, respectively, while the second long-run relationship found, the normalization was carried out in the investment variable. In both models, all coefficients are significant and show the expected signs. The stationarity of these relations cannot be rejected with a *p-value* of 0.30 for the productivity model and 0.37 for the output model. In accordance with the battery of stability tests, the concentrated version of the model is reasonably stable in all cases.[48][49]

Although we estimated two models, one for labour productivity and another for output, we found similar results. The first long-run relationship in each model (equations 1 and 3, see Table 1B.1) shows that investment and imports positively influence labour productivity and output level in the long run, while the second relation found in these models (equations 2 and 4, see Table 1B.1) shows that innovation activities and investment are to a certain extent complementary.

[47] All these tests are available by request.
[48] These tests are available from the authors.
[49] We have estimated the model again, but now considering only the sub-sample 1978-2004 in order to compare these results with our initial estimations for the full period. The findings for the full model and the sub-period considered are very similar to each other. We thus focus our comments on the full model

Table 1B.1: Dynamics of labour productivity and output (statistics in brackets)

	Labour Productivity model		GDP model	
	Δlprod	*Δlinv*	*Δlgdp*	*Δlinv*
$\Delta lprod_{t-1}$	0.42	1.27		
	(5.48)	*(6.60)*		
$\Delta lgdp_{t-1}$			0.29	0.77
			(3.23)	*(3.04)*
Δlgdpusa	0.37	-	0.29	0.55
	(3.96)	-	*(2.18)*	*(1.60)*
Δlim	0.04	-	0.05	-
	(3.45)	-	*(3.25)*	-
Δlim_{t-1}	-0.03	-	-	0.17
	(-2.85)	-	-	*(4.20)*
Δlrer	-0.41	-1.07	-0.33	-1.13
	(-5.47)	*(-4.22)*	*(-4.16)*	*(-5.29)*
$\Delta lrer_{t-1}$	-	-	-0.16	-0.50
	-	-	*(-2.03)*	*(-2.22)*
Δlrd	0.09	0.33	0.12	0.27
	(4.87)	*(5.46)*	*(5.31)*	*(4.35)*
Δlrd_{t-1}	0.08	-	0.10	0.15
	(4.53)	-	*(3.84)*	*(2.16)*
$ecm_{1(t-1)}$	**-1.53**	-1.16	**-0.52**	-0.52
	(-8.45)	*(-2.01)*	*(-7.68)*	*(-2.84)*
$ecm_{2(t-1)}$	-0.55	**-1.62**	-0.44	**-1.47**
	(-8.11)	*(-7.23)*	*(-6.29)*	*(-7.77)*
LR over-identifying restrict. short-run struct. $\chi^2(15)=24.211$ (0.0616)			LR over-identifying restrict short run struct. $\chi^2(9)=15.105$ (0.0881)	

$ecm_1 = lprod - 0.21linv - 0.24lim - 0.24D_{s94}$ (1)

$ecm_2 = linv - 0.31lrd - 0.20D_{s78} - 0.08t$ (2)

$ecm_1 = lgdp - 0.38linv - 0.19lim - 0.42lrer - 0.18D_{s94} - 0.07D_{s78}$ (3)

$ecm_2 = linv - 0.24lrd - 0.24D_{s78} - 0.09t$ (4)

Note: The long-run relations found in the dynamics of both the labour productivity and output models are expressed as an error correction mechanism.

These results are more in agreement with the hypothesis of endogenous growth models, than with the traditional models of growth. The long-run effect of imports and investment on labour productivity and output probably account for both the embodied technological progress associated with capital accumulation and the technology transfer from abroad that are associated with imports. In addition, gains in competitiveness accomplished through the real exchange rate were also seen to give rise to a positive effect on the determination of output level in the long-run. This last finding is in agreement with the development approach to currency management and has been considered a key factor to boost exports, income, employment and savings. The most important channels by which exchange rate levels affect long-run growth are related to investment and technological change.[50] A similar conclusion has been reached by Rodrik

[50] For more details, see Gala (2008).

(2007), who argues that the Chinese economy has made use of the continuous depreciations of its currency as an additional instrument of economic policy to enhance long-run growth.

Interpreting the role played by the deterministic components included in the models is important to understand the stability of our long-run relationships and the role played by some exogenous reforms and shocks. The D_{s78} captures the structural break in our relationships due to the shock associated with the beginning of the reform programmes at the end of 1978. Although "even after 1978, the pace of economic change was slow" (Bramall, 2000, p. 13), nobody questions the fact that the introduction of reform programmes in China to readjust the economy when Deng Xiaoping came to power at the end of the 70s signals the beginning of a new phase in Chinese economic development. The shock captured by D_{s78} implies that after that year investment and output both increased more than the magnitude implied by the rest of the economic variables included in the relationships. This finding is also reasonable given that the process of decentralization and the increase in the presence of the non-state sector, as well as the start of the "open door" policy in China, all favoured the acceleration of output and investment, which in turn affected output and productivity. A similar effect is implied by the shift in relationships captured by D_{s94}. This dummy takes account of the positive effect on labour productivity and output, given that during the 90s a series of continuous reforms, such as the unification of the exchange rate or a tax reform, were implemented by the Chinese government. Finally, the linear trend in the investment relation could be associated with other determinants of investment that are not considered in our model.

However, in order to complete the specification of the models that were estimated and to be more precise in the economic implications of the results, we identified the dynamics of labour productivity and output. The short-run dynamic adjustment structure was estimated by conditioning on the cointegration relations in equations 1 to 4, expressed in terms of error correction mechanisms (ecm). The results are reported in Table B1.1. To save space, the dummy variables are not included.

Furthermore, it is possible to test the direction of the causality in the long and short run. The causality in the long run is established by the significance of the ecm, that is, our long-run relations, while the causality in the short run is analysed through the significance of the lags of our variables.

In the dynamics of the productivity model, it can be observed how the productivity equation adjusts towards equilibrium with the first long-run relationship that is found (ecm_1), while the investment equation is error correcting with the second (ecm_2). In both cases the alpha coefficients are negative and statistically significant. The speed of adjustment towards the long-run equilibrium in both relations is fast and around six months. Similar interpretations are possible with the output model.

Our main findings are consistent with an import-led growth effect and show a positive relation between imports and labour productivity/output. The causality runs in one direction from imports to productivity/output, as can be seen in the coefficients of the error correction mechanism, which are highly significantly negative. We did not find causality running in two directions between imports and productivity/output given that imports become weakly exogenous in our estimated models. The implication of weak exogeneity of one or more variables is that they influence the long-run stochastic path of the other variables of the system, although at the same time they are not influenced by the other variables.

In addition, we found an investment-led growth effect. However, we did not find that the increase in investment causes imports directly, as Rodrik (1995) suggests. His hypothesis claims that imports are endogenously determined by investment, and the direction of the causality runs from investment to imports. The increase in imports then encourages exports and hence economic growth. However, according to our estimations, imports become exogenous and they are not influenced by investment. Our results imply that investment and imports account for labour productivity and output directly in the long run, suggesting that embodied technological progress associated with capital accumulation and imports probably have played a significant role in Chinese economy.[51]

Additionally, we found that R&D expenditure directly stimulates investment and has an indirect positive effect on productivity and output. This result, which is robust to different

[51] See Madsen (2002).

specifications, is interesting in the sense that R&D has two faces. On the one hand, it generates new innovations and facilitates the assimilation of these new discoveries (Griffith et al., 2004; Cameron et al., 2005). And on the other hand, in accordance with Howitt and Aghion (1998), innovation activities and capital accumulation are complementary and could play a critical role in long-run growth. Thus, our results are more in agreement with the conclusions drawn by these authors.

In the short-run dynamics, we can find common effects in the two models estimated. First, our results indicate that the real exchange rate negatively affects productivity/output and investment growth in the short-run, which can probably be explained by the deterioration of terms of trade. Second, innovation activities measured by R&D expenditure have played a key role in the process of growth and stimulate investment. Third, we find a procyclical effect of foreign economic conditions on output and productivity that probably captures the influence of the international business cycle. Finally, we found that the increase in imports stimulates investment in the output model.

References

Adams, F.G., Gangnes B., and Shachmurove, Y., (2006). 'Why is China so Competitive? Measuring and Explaining China's Competitiveness.' *World Economy* 29 (2), pp.95-122

Aschauer, D., (1988). 'Government spending and the "falling rate" of profit.' *Journal of Economic Perspectives* 12 (May), pp.11-17

Aschauer, D., (1989). 'Is public expenditure productive?' *Journal of Monetary Economics* 23 (2), pp.177-200

Aw, B. Chung, S., and Roberts, M., (2000). 'Productivity and Turnover in the Export Market: Micro-level Evidence from the Republic of Korea and Taiwan (China).' *World Bank Economic Review* 14 (1), pp.65-90.

Baldwin, R., and Seghezza, E., (1996). 'Trade-induced investment-led growth.' NBER Working Paper No 5582

Barro, R., (1991). 'Economic Growth in a Cross Section of Countries.' *The Quarterly Journal of Economics* 106 (2), pp.407-447

Bernard, A. and Bradford J., (1999). 'Exceptional Exporter Performance: Cause, Effect, or Both?.' *Journal of International Economics* 47 (1), pp.1-25

Blomstrom, M., Lipsey, R. and Zejan, M., (1996). 'Is fixed investment the key to economic growth?' *The Quarterly Journal of Economics* 111 (1), pp.269-276.

Bond, S., Leblebicioglu, A., and Schiantarelli, F., (2004). 'Capital Accumulation and Growth: A New Look at the Empirical Evidence.' Economics Department. Boston College Working Paper, 591.

Bramall, C., (2000). 'Sources of Chinese Economic Growth 1978-1996.' Studies on Contemporary China. Oxford University Press.

Cameron, G., Proudman, J. and Redding, S. (2005). 'Technological convergence, R&D, trade and productivity Growth.' *European Economic Review* 49, pp.775-807.

Caruso, M., (2002). 'Procyclical Productivity and Output Growth in China: An Econometric Analysis.' *Open economies review* 13, pp.251–274

Chow, G., (1993). 'Capital Formation and Economic Growth in China.' *The Quarterly Journal of Economics*. 108 (3), pp.809-842.

Chow, G., (2008). 'Another look at the rate of increase in TFP in China.' *Journal of Chinese Economic and Business Studies* 6, pp.219-224

Chow, G., and Lin, A., (2002). 'Accounting for economic growth in Taiwan and mainland China: a comparative analysis.' *Journal of Comparative Economics* 30, pp.507-530.

Chuang, Y., (1998). 'Learning by doing, the Technology gap, and growth.' *International Economic Review* 39 (3), pp.697-721

Chuang, Y., (2000). 'Human Capital, Exports, and Economic Growth: A causality analysis for Taiwan, 1952-1995.' *Review of International Economics* 8, pp.712-720.

Clerides, S., Lach, S., and Tybout, J., (1998). 'Is learning by exporting important? Micro-dynamic Evidence from Colombia, Mexico, and Morocco.' *The Quarterly Journal of Economics* 113 (3), pp.903-47.

Cuadros, A., Orts, V., and Alguacil, M., (2004). 'Openness and growth: Re-examining foreign direct investment, trade and output linkages in Latin America.' *Journal of Development Studies* 40 (4), pp.168-193

De Long, J. B., and Summers, L., (1991). 'Equipment Investment and Economic Growth.' *The Quarterly Journal of Economics* 106 (2), pp.445-502

De Long, J. B., and Summers, L., (1992). 'Equipment Investment and Economic Growth: How strong is the nexus?' *Brookings Papers on Economic activity* 1992 (2), pp.157-211

Easterly, W., and Levine, R., (2001). 'It's Not Factor Accumulation: Stylized Facts and Growth Models.' *World Bank Economic Review* 15, pp.117-219

Esfahani, H., (1991). ‘Exports, Imports, and Economic Growth in Semi-Industrialized Countries’. *Journal of Development Economics* 35 (1), pp.93-116.

Feder, G., (1983). ‘On exports and economic growth.’ *Journal of Development Economics* 12 (1-2), pp.59-73

Frankel, Jeffrey A.; and David Romer, (1999). ‘Does Trade Cause Growth?’ *The American Economic Review* 89 (3), pp.379-394

Gala, P. (2008). ‘Real Exchange Rate Levels and Economic Development: Theoretical Analysis and Empirical Evidence.’ *Cambridge Journal of Economics* 32, pp.273-288.

Giles, J., and Cara L. W., (2000). ‘Export-led growth: A survey of the empirical literature and some non-causality results. Part I.’ *Journal of International Trade and Economic Development* 9 (3), pp.261-337

Griffith, R., Redding, S, and. Reenen, J.V. (2004). ‘Mapping the two faces of R&D: Productivity Growth in a Panel of OECD Industries.’ *The Review of Economics and Statistics* 86, pp.883-895.

Grossman, G. and Helpman, E., (1991). ‘Innovation and Growth in the Global Economy’. Cambridge, Massachusetts, MIT Press.

Helpman, E., and Krugman, P., (1985). ‘Market Structure and Foreign Trade’. The MIT Press.

Helpman, E., (1988). ‘Growth Technological Progress and Trade.’ *Empirica Austrian Economic Papers* 5 (1), pp.5-25

Holz, C. A., (2006). ‘New Capital estimates for China.’ *China Economic Review* 17 (2), pp.142-185

Hendry, D., and Mizon, F., (1993). ‘Evaluating econometric models by encompassing the VAR’. In PC.B. Philips (ed).Models, methods and application of econometrics: Essays in Honor of A.R. Bergstron. MIT Press: Cambridge Mass.

Howitt, P., (2000). ‘Endogenous Growth and Cross-Country Income Differences.’ *American Economic Review* 90 (4), pp.829- 846

Howitt, P., and Aghion, P., (1998). ‘Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth.’ *Journal of Economic Growth*. 3 (2), pp.111-130

Hsiao, F., and Hsiao, M., (2006). ‘FDI, exports, and GDP in East and Southeast Asia—Panel data versus time-series causality analyses.’ *Journal of Asian Economics* 17 (6), pp.1082-1106

Hu, Z., and Khan, M., (1996). ‘Why is China Growing So Fast?’ IMF Working Papers, No. 96/75.

Irwin, D., and Tervio, M., (2002). ‘Does trade raise income? Evidence from the Twentieth century.’ *Journal of International Economics* 58 (1), pp.1-18

Jin, J.C, (2004). ‘On the relationship between openness and growth in China: Evidence from provincial time series data.’ *The World Economy* 27, pp.1571-1582

Johansen, S., (1988). ‘Statistical Analysis of Cointegration Vectors.’ *Journal of Economic Dynamics and Control.* 12 (2-3), pp.231-254

Johansen, S. and Juselius, K., (1990). ‘Maximum Likelihood Estimation and inference on cointegration-with Applications to the Demand for money.’ *Oxford Bulletin of Economics and Statistics* 52 (2), pp.169-210.

Johansen, S. and Juselius, K., (1994). ‘Identification of the Long-run and the Short-run structure. An application to the ISLM model.’ *Journal of Econometrics* 63 (1), pp.7-36

Johansen, S., (1995). ‘Likelihood-Based inference in cointegrated vector auto-regressive models’. Advance Texts in Econometrics. Oxford University Press.

Jones, C., I. (1995). ‘Time series Tests of endogenous growth models.’ *The Quarterly Journal of Economics* 110 (2), pp.495-525

Juselius, K., (2007). ‘The cointegrated VAR model: Econometric methodology and macroeconomics applications’. Oxford University Press.

Juselius, K., and MacDonald, R., (2006). ‘International parity relationships between the USA and Japan.’ *Japan and the world economy* 16 (1), pp.17-34

Kunst, R., and Marin, D., (1989). 'On exports and Productivity: A casual analysis.' *Review of Economics and Statistics* 71 (4), pp.699-703

Kwan, A., Wu, Y. and Zhang, J., (1999). 'Fixed Investment and Economic Growth in China.' *Economics of planning* 32 (1), pp.67-79.

Lardy, N. R., (1995). 'The role of foreign trade and investment in China's economic transformation.' *China Quarterly* 144, pp.1065-82

Lee, J.W. (1995). 'Capital goods imports and long-run growth.' *Journal of Development Economics* 48, pp.91-110.

Lin, S., (1999). 'Export Expansion and Economic Growth : Evidence from Chinese Provinces.' *Pacific Economic Review* 4, pp.65-77

Liu, X., Song, H., and Romilly, P., (1997). 'An empirical investigation of the causal relationship between openness and economic growth in China.' *Applied Economics*. 29 (12), pp.1679-86

Liu, X., Burridge, P., Sinclair, P. J. N., (2002). 'Relationships between economic growth, foreign direct investment and trade: evidence from China.' *Applied Economics* 34 (11), pp.1433-1440.

Lopez, R. A., (2005). 'Trade and Growth: Reconciling the Macroeconomic and Microeconomic Evidence.' *Journal of Economic Surveys* 19(4), pp.623-648

Love, J., and Chandra, R., (2005). 'Testing export-led growth in Bangladesh in a Multivariate VAR framework.' *Journal of Asian Economics* 15 (6), pp.1155-68

Lucas, R., (1988). 'On the mechanisms of economic growth.' *Journal of Monetary Economics* 22, pp.3-42.

Madsen, J. B., (2002). 'The causality between investment and economic growth.' *Economic Letters* 74 (2), pp.157-163.

Marin, D., (1992). 'Is the Export-led Growth Hypothesis valid for Industrialized countries?'. *Review of Economics and Statistics* 74 (4), pp.678-88

Mazumdar, J. (2001). 'Imported machinery and growth in LDCs.' *Journal of Development Economics* 65, pp.209-224.

Melitz, M., J., (2003). 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica* 71(6), pp.1695-1725

Nielsen, H., (2004). 'Cointegration analysis in the presence of outliers.' *Econometrics Journal* 7 (1), pp.249-271

Nielsen, H., and, Christensen, A., (2005). 'US Monetary Policy 1988-2004: An empirical Analysis.' Finance Research Unit, Institute of Economics, University of Copenhagen. WP No. 2005/01.

Nolan, P., (1995). 'China's rise, Russia's Fall'. London, Macmillan.

Noguer, M., and Siscart, M., (2005). 'Trade raises income: a precise and robust result.' *Journal of International Economics* 65 (2), pp.447-460

Pack, H., and Page, J., (1994). 'Accumulation, exports and growth in the high-performing Asian economies.' *Carnegie-Rochester Conferences series on public policy* 40 (June), pp.199-235

Panagariya, A., (2000). 'Evaluating the Case for Export Subsidies', Policy Research Working Paper 2276, World Bank.

Pepper, S., (1996). 'Radicalism and education reform in Twentieth Century China'. Cambridge, Cambridge UP.

Prasad, E., and Rajan, R., (2006). 'Modernizing China's Growth Paradigm.' *American Economic Review* 96 (2), pp.331-336

Qin, D., Cagas, M., Quising, F. and He, X., (2005). 'How much Does Investment Drive Economic Growth in China?' Queen Mary University of London, Department of economics, working paper No 545.

Rahbek, A., Hansen, E. and Dennis, J, (2002). 'ARCH innovations and their impact on cointegration rank testing.' Department of Statistics and Operations, University of Copenhagen. WP Nº 22, Center for analytical Finance.

Rebelo, S., (1991). 'Long-Run Policy Analysis and Long-Run Growth.' *Journal of Political Economy* 99 (3), pp.500-521.

Riezman, R., Summers P.M, and Whiteman C., (1996). 'The engine of Growth or its handmaiden? A time series assessment of export-led growth.' *Empirical Economics*. 21 (1), pp.77-113.

Rodriguez, F.; and Rodrik D., (2001). 'Trade policy and economic growth: A skeptic's guide to the cross-national evidence' in B.S. Bernake and K. Rogoff (eds.) NBER Macroeconomics Annual 2000, The MIT press Cambridge.

Rodrik, D., (1995). 'Getting interventions right: how South Korea and Taiwan grew rich.' *Economic Policy* 10, pp.53-107.

Rodrik, D., (1996). 'Understanding Economic Policy Reform.' *Journal of Economic Literature* 34 (March), pp.9-41

Rodrik, D., (1999). 'New Global Economics and Developing Countries: Making the Openness Work'. Policy Essay No. 24. Washington D.C. Overseas Development Council. Johns Hopkins University Press, Baltimore.

Rodrik, D. (2007). 'The Real Exchange Rate and Economic Growth: Theory and Evidence. Undervaluation is good for growth, but why?' Working paper. Harvard University.

Romer, P., (1986) 'Increasing Returns and Long-Run Growth.' *The Journal of Economics Perspectives* 8 (5), pp.3-22

Romer, P., (1987). 'Growth Based on increasing returns due to specialization.' *American Economic Review* 77 (2), pp.56-62.

Romer, P., (1990). 'Endogenous Technological Change.' *Journal of Political Economy* 98 (5), S71-102.

Shan, J.; and Fiona S., (1998). 'On the export-led growth hypothesis: the econometric evidence from China' *Applied Economics* 30 (8), pp.1055-1065

Shi, Y. (1998). 'Chinese firms and Technology in the Reform Era.' Routledge Studies in the Growth Economies of Asia.

Siebert, H. (2007). 'China: Coming to Grips with the new global player.' *The World Economy* 30, pp.893-922.

World Bank. (1993). 'The East Asian Miracle', a World Bank Policy Research Report, Oxford: Oxford University Press.

Wu, Y.,. (2000). 'Productivity, Growth and Economic Integration in the Southern China Region.' *Asian Economic Journal* 14 (1), pp.39-53.

Wu, Y., (2004). 'China's Economic Growth. A miracle with Chinese Characteristics'. Routledge Studies on the Chinese Economy.

Yao, S., (2006). 'On economic growth, FDI and exports in China.' *Applied Economics* 38, pp.339-351

Young, A., (1991). 'Learning by doing and the dynamics effects of international trade.' *The Quarterly Journal of Economics* 106 (May), pp.369-405

Young, A., (1992) 'Tale of two cities: Factor Accumulation and Technical change in Hong Kong and Singapore'. NBER Macroeconomics Annual.

Young, A., 1994. "Accumulation, exports, and growth in high-performing Asian economies: A comment" *Carnegie-Rochester Conferences series on public policy* 40 (June), pp.237-250.

Yu, Q., (1998). 'Capital investment, international trade and economic growth in China: Evidence in the 1980-90s.'. *China Economic Review* 9 (1), pp.73-84.

Yusuf, S., (1994). 'China's Macroeconomic Performance and Management during Transition.' *The Journal of Economic Perspectives* 18 (2), pp.71-92

Chapter II

Equipment Investment, Output and Productivity in China

2.1 Introduction

At the beginning of the nineties J. Bradford De Long and Lawrence H. Summers highlighted in a series of influential papers that there were good reasons and quantitative evidence in supporting the point of view that machinery and equipment investment might be strongly associated with economic growth. Specifically, they found "those countries with high equipment investment grew extremely rapidly, even controlling for a number of other factors" (De Long and Summers, 1992, p.158). They identified at least three arguments that support their view. Firstly, historical accounts of economic growth invariably assign a central role to mechanization. Secondly, discussions of economic growth in development economies and the new growth theory traditions highlight external economies as an important cause of growth. In addition, given that the equipment sector is one of the most intensive in research and development, it is reasonable to believe that it could be a source of external economies. Thirdly, countries that pursue a government-led "development state" approach to development, seems to have higher equipment investment rates, lower equipment prices, and enjoy of faster economic growth (De Long and Summer, 1991, pp.447-448).

From our point of view, if this association is correct, then the rapid growth in China and its enormous investment effort over recent decades constitutes an interesting case of study and a "natural" laboratory to analyze the role of equipment investment and its interaction with other sources of growth in its recent economic performance. First, because the fast growth experimented by the Chinese economy is unquestionable that can be considered of the type government-led "development state" approach to development. The underlying idea is that countries which adopt more efficient mechanisms to allocate their resources are more likely to grow than those that have a structure similar to poorer economies. The Chinese government initiated gradually the economic reforms to reach a market-oriented economy and launched the industrialization process by transforming the main and more strategic economic sectors in the sixties until the present-day, given the fail of the Great Leap Forward in the fifties. It is plausible to believe that a more liberalized economy, allocates the economic resources and implements the appropriated economic policies more efficiently, enjoying of faster growth.

Secondly, China has undergone high investment rates in recent decades, with a significant contribution of equipment as opposed to other components of capital accumulation such as infrastructures which experienced a rapid growth, with massive investment projects during the pre-reform period before the end of seventies and displayed a modest growth onwards. However, the spectacular increase in the demand of such goods stimulated a more efficient use of the existing infrastructure, especially of the current transport system.

Thirdly, although imports in equipment have been one of the strategies of China's development since the sixties, a change in the sources of provisioning from Soviet block and East European countries to occidental economies with a higher degree of development took place after the fail of the Great Leap Forward. Firstly from Japan, which become one of the most significant providers in equipment investment since the sixties until the present-day, and after that, the trade partners were progressively diversified to others countries that currently belong to the EU and US. These types of capital goods, especially in equipment, are intensive in R&D and are potential generators of the spillovers or external economies mentioned by De Long and Summers which could be one of the stronger causes of economic growth.

In addition to these arguments, and from a theoretical point of view, the recent endogenous growth literature, especially the Schumpeterian version of the endogenous growth theory, provide formal support to the existence of long-term relationship between investment and growth, where the causation runs from investment to output and productivity. In this sense, capital accumulation could be a source of economic growth if embodied technological progress exists and whether among the determinants of capital accumulation the supply factors predominate (Madsen, 2002). Besides, Howitt and Aghion (1998, p. 112) argued that “capital accumulation and knowledge can determine the level of output in the long-run, being both factors complementary processes and playing a significant role on economic growth .In fact, capital accumulation could be a source of long-run growth only if it has followed by technological progress given the diminishing returns on capital accumulation. Alternatively, technological progress can not be sustained indefinitely without the accumulation of capital to be used in the R&D process which creates innovations and in the production process that implements them”.

Although the significant contribution of equipment investment on the economic activity in China seems undeniable, there are additional factors that could promote output and labor productivity in the steady state (human capital, R&D expenditure, openness and infrastructures). Human capital, as measure of skill of the population, plays a crucial role in improving the productivity of workforce and in its capacity of absorbing or adapting the spillovers of foreign technology. Although countries encourage technology imitation through intermediates or capital imports and foreign direct investment, it is the learning effect which limits its own technology absorptive capability (Borensztein et al., 1998). In addition, the degree of openness, especially exports, has substantial benefits on labor productivity and output in the long-run for several reasons. Firstly, foreign trade is one of the most important conduits for the transmission of the foreign technology. Secondly, competitive pressure made by foreign firms enhances domestic firms to invest in R&D expenditure to survive in the international market, being more efficient and stimulating productivity. Lastly, access to a greater market may create gains through economies of scale. On the other hand, the innovations measured by R&D expenditure and investments are closely related and should be complementary to boost labor productivity and output in the long-run (Howitt and Aghion, 1998; Howitt, 2000). Finally, non-equipment investment such as productive infrastructures, for example railways and highways, are also considered additional factors of long-run growth (Aschauer, 1988 and 1989). The improvement in the endowment of infrastructures could enhance the productivity of existing resources through the positive externalities that creates. In addition it could stimulate the increase of other types of investment, given the improvement of the profitability of investment projects due to reduced cost or to improved accessibility to other markets.

In this context the aim of this paper is threefold. Firstly, we provide evidence of the role played by equipment investment as determinant of output and labor productivity in China for the period 1962-2004. To the best of our knowledge there is not evidence of the effect of equipment investment on labor productivity and output in China. Secondly, we assess its robustness in allowing for other relevant sources of economic growth, and finally, we analyze the role played by these different factors on long-run growth. For this purpose we focused our analysis on two factors that have apparently played a relevant role in account for China's growth, namely, equipment investment and exports. However, as we are aware of the close relationships between equipment investments with other relevant variables for growth we have included R&D expenditure, human capital and infrastructures in our analysis. We start up our study exploring the link among equipment investment, R&D expenditure, exports, and the real exchange rate as the main determinants of labor productivity and output in the short and long-run, that is, our base model. After that, we included human capital and infrastructures in our augmented model given the strong relationship of these variables with equipment investment as factors to promote labor productivity and output in the long-run. From a methodological point of view, we employed as statistical framework for the analysis the cointegrated VAR model. This methodology allows us to avoid the endogeneity problem in what extent it is based on a joint modeling of our variables, where their exogeneity or endogeneity is examined and where certain restrictions are imposed until the most irreducible form is reached. Finally, this methodology lets us to distinguish between the short and long run effects. Our results provide evidence that equipment investment and exports are among the most important determinants of both labor productivity and output in the long-run in China, even controlling by other sources of growth. Furthermore, when human capital and infrastructures are included, we found that both positively affects to labor productivity and output in the long-run. Finally, our findings provide robust evidence that R&D expenditure enhances equipment investment on the long-run growth.

The rest of the paper is set out as follows. Section 2 contains a literature review on the relationship between equipment investment and its related variables and economic growth. Section 3 contains the description of the variables considered and the methodology. Section 4 the empirical results are presented. Section 5 includes the conclusions drawn.

2.2 Literature Review

If Solow type economic growth models are correct, the long run growth of productivity is given by the exogenous growth rate of technological progress. In this setting neither capital accumulation nor government policies can have any effect on long run growth rate. However, the new growth theory gives technological change a bigger role in the growth process, stressing the need to model the market forces that endogenously determinate it. In these models, innovation activities enhance output and labor productivity in the long run by increasing the qualities and productivity of different factor in the production process and stimulating capital investment. Alternatively, the "AK" models and the Schumpeterian version of endogenous growth theory developed by Aghion and Howitt (1992) emphasized the strong association between capital accumulation and long-run economic growth. In both approaches capital accumulation is the most important factor which causes economic growth, but only the last one highlight the importance of embodied technological progress establishing a complementary point of view with Solow model.[52] Besides, investment and innovation activities maintain a close relationship given that "technological innovations are typically embodied in a durable good, either physical or human capital" (Aghion and Howitt, 1999, p.93). Nevertheless, there

[52] According with Aghion and Howitt (2007, p.80) Neoclassical theory can be seen as a special case of modern endogenous growth theory, the especial case in which the marginal productivity of efforts to innovate has fallen to zero.

are good reasons to believe that among the components of capital accumulation are machinery and equipment investment the best candidates to incorporate technological progress. As De Long and Summers (1991 and 1992) pointed out those countries with higher equipment investment rates tend to grow faster. According to them, these findings are likely related with that the equipment investment sector is intensive in R&D expenditure, and with a research sector highly "capital-using" and where external economies could exist. They emphasize the empirical relevance and the interdependence of these factors, capital accumulation and technological progress, influencing the dynamics of output and labour productivity, stressed in the Schumpeterian growth model. Capital accumulation required new and advanced technology embodied in new investments, given the diminished returns of capital, and at the same time, new technologies need investments to implement them in the production process which favors its accumulation and boosts economic development.

However it is difficult to believe that until now the Chinese economy has had comparative advantage in the production of R&D intensive equipment investment, instead the Chinese economy, probably as in the case of other developing countries, have made use of imported capital goods from advanced economies with R&D intensive equipment sectors. The access to cheaper capital goods from more developed countries has two complementary effects; first, it allows to developing countries to accumulate more, and more efficient, capital; and second, imported capital goods become a source of positive spillovers for recipient economies. Related with this last effect, the existence of domestic innovation activities acquires a great importance. The domestic innovation activities facilitates a more efficient use of imported capital goods and the spread of embodied technological progress to the rest of the economy, encouraging additionally capital accumulation and domestic imitation and innovation (Lee, 1995; Eaton and Kortum, 2001; Boileau, 2002; Caselli and Wilson, 2004).

The empirical relationship between equipment investment and economic growth has been widely studied with mixed results. On the contrary of De Long and Summers' findings, Auerbach et al. (1994) argued that the results of De Long and Summers (1992) exaggerate the social returns to equipment investment. They used the data set of De Long and Summers and found that if Botswana was removed from the sample the effect of equipment investment on economic growth was consistent with the predictions of the traditional models of economic growth. In addition, Dellas and Koubi (2001) argued that De Long and Summers missed the social capabilities that are crucial for poor countries to benefit through industrialization. These authors, like Temple and Voth (1998), found that industrial employment is more determining than equipment investment in the development process of low-moderate income countries. From another point of view, Griliches and Jogerson (1966), Hulten (1992) and Greenwood et al. (1997) found evidence that embodied technological change positively affects to long-run productivity. Conversely, Berglas (1965) found no evidence of embodied technological progress and supported the Solow type model. Finally, the evidence on the relation between equipment investment and economic growth to our knowledge is non existent for China. Nonetheless, the majority of the studies found that capital accumulation is one of the determinants of long-run growth in China (Chow, 1993; Yusuf, 1994; Yu, 1998; Kwan et al., 1999; Herrerias and Orts, 2009).

Together with equipment investment and R&D activities, considered until this moment, there are additional factors, however, that could account for the dynamics of economic growth in an economy such as human capital, exports and infrastructures. The introduction of these new variables follows four objectives: to check the robustness of equipment investment, to analyze the relationship that exists among them, to examine their direct influence on labor productivity and output, and finally, to avoid the bias of our estimates by the omission of relevant variables in the empirical model specification.

Human capital is a recurrent factor considered to promote long-run growth in the literature (Uzawa, 1965; Lucas, 1988; Romer, 1990; Young, 1991; Caballé and Santos, 1993; Aghion and Howitt, 1998; and Barro, 2001). Among the different mechanisms through that human capital could enhance productivity and output one of the most immediate is that labor productivity may rise in response to increase of workers skills. It is expected that workers which are more educated and more qualified contribute to increase firm's productivity. Besides, the knowledge acquired by qualified workers, namely, human capital, could also generates innovations or improves the ability of an economy to absorb, adapt or imitate new technologies affecting additionally and positively output and productivity, reducing the technological gap from advanced countries (Benhabib and Spiegel, 1994; Nelson and Phelps, 1996, Borenztein et al, 1998; Temple and Voth, 1998 and Hendricks, 2000). Thus, innovations are not confined to R&D expenditure, but also to human capital. Skills of workers could increase the productivity of physical capital, especially for machinery and equipment, through improving the learning-by-doing mechanism, being both, R&D activities and human capital, relevant factors and raising efficiency and productivity. Finally, there are additional education externalities that could affect long-run growth; for example, skilled workers can show their knowledge to unskilled workers improving their productivity or may be external social impacts given that more educated workers are associated with better environment, greater social cohesion, community participation, etc. (Sianesi and Reenen, 2003).

Openness to trade has been also considered an additional factor that stimulates long-run growth through different channels and mechanisms. The scale effects, the knowledge spillovers as well as the ability to imitate the foreign competitor products, are mechanisms that could speed up growth.[53] Furthermore, competitive pressures favour that firms invest in R&D to survive in the international market which enhances productivity and output. In these types of models with self-selection hypothesis, only the most productive firms can survive and participate in the trade activity, given the sunk cost associated with the entry to foreign markets (Melitz, 2003). Thus, economies with initially high export experience are able to produce relatively new goods with higher technological intensity whereas those with less experience deal with standardized goods with lower technological content. In addition, there is evidence that when the firms are already in the foreign market, they become more productive given the existence of learning-by-exporting effects, and generates positive externalities and spillovers in the rest of the economy, since more efficient management and organizational styles, labor training and improved production techniques are adopted (Feder, 1983). Besides, exporting experience seems that is significant in determining the export mix, which suggests that there

[53] See for example Grossman and Helpman (1991) or Rivera-Batiz and Romer (1991).

may be a trade-induce component of learning-by-doing in foreign trade specialization (An and Iyigun, 2004).[54] Finally, exporting activity allows foreign exchange constraints to be relaxed, thus permitting increased imports of capital and intermediate goods (Esfahani, H.S., 1991 and Riezman et al., 1996).[55, 56]

Since the seminal papers developed by Aschauer (1988, 1989) infrastructure has been considered a factor to boost long-run growth through the positive externalities that generate in an economy. Productive infrastructure such as highways or railways can expand productivity capacity of an area by increasing resources and by enhancing the productivity of existing resources (Munnel, 1992). Moreover, infrastructure can stimulate other forms of investment, which is favoured by the decrease in the cost of intermediate inputs and provides highly valuables services that firms employ in their production process. Hence, it allows increase firm's ability to engage in new productive activities (Munnel, 1992; Fernald, 1999; Röller and Waverman, 2001 and Hulten et al. 2006). However, probably in the case of infrastructures, the most relevant question is how productively the economy uses these infrastructures, more than the direct effect on output and labour productivity of its provision. Empirically, the direction of the causality and the positive, negative or negligible effect of infrastructures on economic growth seems mixed. Aschauer (1989) in his pioneer study found that infrastructure accounted for labor productivity in the US, where the direction of the causality runs from infrastructure to productivity. Similar results found Munnell (1990), Eisner (1991), Canning et al. (1994), Easterly and Rebelo (1993) and Flores de Frutos and Pereira (1993) to cite just a few. In contrast, Deverajan et al. (1996) found in a study of 43 developing countries that transports and communications expenditures have a negative correlation with per-capita GDP growth. Similar results were found by Holtz-Eakin (1994) and Garcia-Mila et al. (1996) with different specifications.

---

[54] See also Young (1991), Chuang (1997), Goh and Olivier (2002).

[55] Regardless of these arguments there are authors who show certain scepticism about the positive effects of openness to trade on economic growth (Rodrik, 1999 and Rodriguez and Rodrik, 2001).

[56] There is immense empirical literature on the relationship between trade and economic growth with mixed results. Recent surveys can be found in Baldwin (2003) and López (2005).

The evidence on the relation between these additional factors and economic growth in China is unequal. Thus, Wang and Yao (2003) and Heckman (2005) found that human capital has contributed positively on economic growth in China.[57] As well, there is a lot of empirical work highlighting that trade, especially exports, has played a relevant role in the Chinese development (Shan and Sun, 1998; Siebert, 2007; Herrerias and Orts, 2009). In many cases the causality found between exports and output or labor productivity is bidirectional. Nonetheless, Hsiao and Hsiao (2006) found that exports do not cause output. Lastly, the evidence of the relationship between infrastructure and economic growth on China has mainly been studied at a regional level. On the one hand, Démurger (2001) found that transport facilities are a key differentiating factor in explaining the growth gap and point to the role of telecommunication in reducing the burden of isolation. On the other hand, Fan and Zhang (2004) found that rural infrastructure and education play a more important role in explaining the difference in rural non-farm productivity than agricultural productivity.

In all cases, the empirical work in this field has been subject to debate on the endogeneity[58] and the direction of the causality among the different factors mentioned and economic performance. For example Bils and Klenow (2000) found reverse causality between growth and human capital, Helpman, (1988) find empirical evidence on countries with higher incomes engage in more trade, and in Tatom (1993) we can find that the causation may be move more from output to infrastructure capital.

2.3. Data and Methodology

In the empirical analysis we employed annual data from the Chinese economy from 1962 to 2004. Our data set alternatively consists of GDP *(lgdp)* and labor productivity[59] – output per worker- *(lprod)*, jointly with net equipment investment (*lifeq*), R&D expenditure[60] (*lrd*), export-

[57] See also Lai et al. (2006), Liu (2007)

[58] This aspect has been especially relevant in the trade and growth empirical literature. See for example Frankel and Romer (1999)

[59] In this paper labor productivity and human capital were corrected by applying the methodology suggested by Nielsen (2004).

[60] We took total expenditure on scientific research from NBS as proxy variable of R&D expenditure.

to-GDP ratio – exports in FOB terms – (*xgdp*), the real exchange rate (*lrer*),[61] the increases of human capital *(Δhc)* and two measures of infrastructures *(lrprail* and *lrphigh)*; all the variables are in real terms[62] and in logs (except the ratio of exports to GDP and the increases of human capital). Our basic data source was the National Bureau of Statistics of China (NBS), except for equipment investment and human capital. We took the equipment investment variable from Holz (2006) who made a precise effort to obtain a measure of the capital stock based on the data of investment in fixed assets from the NBS.[63,64] Besides, we took human capital, *(hc)* – per capita years of schooling- from Wang and Yao (2003) and we extended this data to 2004 making a small variation in the construction of the variable[65]. Finally, we employed two measures in those models in which we introduced infrastructures, firstly the number of passengers-Km of railways (100 million people passenger-km) – *lrprail*- and secondly the number of passenger- Km of highways (100 million people passenger-km) – *lrphigh*-. Thus, we considered not only infrastructure investment but also the demand of infrastructures.[66]

As a statistical framework for analysis, and given the potential interdependence and endogeneity of the variables considered, we used the cointegrated VAR model proposed by Johansen (1988), Johansen and Juselius (1990), Johansen and Juselius (1994) and Johansen (1995) as the most convenient methodology for the description of our macroeconomic time series data. One of the advantages of this methodology is the possibility of combining long-run and short-run information in the data by exploiting the cointegration property (Juselius, 2007). Besides, researchers do not impose any restrictions prior to starting the analysis with regard to the exogeneity or endogeneity of our variables considered. Thus we allow that the data to reveal

[61] The real exchange rate has been calculated using the nominal exchange rate between the Chinese currency and the US $ (Renminbi/$) and the respective consumer price indices (CPIs).
[62] We have deflated R&D expenditure with the GDP deflator.
[63] See Holz (2006) for further details on the construction of this variable, depreciation and deflators. In addition, in Appendix 2B is possible to see an extension of this research showing the robustness of these results.
[64] Equipment investment and infrastructure are components of capital accumulation in the supply side. It is expected that if among the determinants of capital accumulation predominate the supply factors a long-run relationship between equipment investment, infrastructure and output or labor productivity exists due the embodied technological progress. On contrary, if the demand factors predominate it is expected only short-run effects on output and labor productivity (Madsen, 2002).
[65] See Appendix 2A for further details.
[66] Investment in infrastructure is not available in NBS, thus we employ two indicators as proxy variable of investment in infrastructure given that they should be correlated.

the nature and interactions among them given the complex relationship that exists from an economic point of view.

In particular, we start with an unrestricted VAR model, with a restricted linear trend in the cointegration space[67]:

$$\Delta X_t = \alpha\beta' \begin{pmatrix} X \\ t \\ D_s \end{pmatrix}_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \sum_{i=0}^{k-1} \theta_i \Delta D_{st-i} + \varphi D_t + \mu + \varepsilon_t \tag{1}$$

$$\varepsilon_t \sim NIID(0, \Omega) \quad t = 1....T$$

Where X_t is the vector of potentially endogenous variables in the different models that we go on to specify; α and β are matrices of dimension $p \times r$; α denotes the direction and speed of adjustment toward equilibrium and β' are the matrix of the cointegrated vectors. D_{st} is the restricted matrix of the level-shift dummies, $(\Gamma_i, \theta_i, \varphi)$ are the coefficients of the unrestricted matrix in the short run and dummies respectively and μ is a vector of unrestricted constants. Finally, we assumed that the error term, ε_t, is an i.i.d. Gaussian sequence N (0, Ω) and the initial values, $X_{-k+1},\ldots X_0$, are fixed.

Given that the analysis of a system containing a larger number of potentially endogenous variables is econometrically very demanding, as in Juselius and MacDonald (2000 and 2004), a specific-to-general approach in the choice of variables will be adopted. Initially, we start the analysis with a five-dimensional system that alternatively includes the GDP or labor productivity, jointly with net equipment investment, R&D expenditure, export-to-GDP ratio, and the real exchange rate (the base model).Then we extended it by the inclusion of human capital and two measures of infrastructures.

The stationary property of our variables is explored with two traditional unit root tests as it is possible to see in the Appendix 2A. We concluded that the best characterization of our stochastic process is to accept that all variables are integrated of order one, except human capital, which is integrated of order two. In this last case, we transformed the variable in the first differences to employ the cointegrated VAR model methodology.

---

[67] The reason to include a trend in the cointegration space is that when the data are distinctly trending we need to allow for linear trends in the cointegration relationships when testing for the cointegration rank.

Given the significant economic changes in the Chinese economy throughout the period under study we have included two level shifts dummies which are restricted to the cointegration space to guarantee a reasonable stability of the parameters estimated in the concentrated model version. The first level shift was introduced in 1970, D_{s70}, while the second level shift, D_{s85}, was introduced in 1985. Besides, we have introduced two unrestricted permanents dummies, one for the year 1976, dum_{76p} and another for 1989, dum_{89p}. The level shift dummy restricted to the cointegration space in 1970 and the permanent dummy in 1976 attempt to capture the economic consequences since the Cultural Revolution. The explanation of the second level shift corresponds to the slowdown in the output and labor productivity growth rates at the end of second half of the eighties, following the unprecedented trade deficit of 1985. Finally, the dummy in 1989 likely corresponds to the reforms to control the high inflation rate at the end of the eighties and to the decrease in external financing given the events which took place in *Tienanmen Square* in that year.

In all the models estimated with two lags is enough to avoid the autocorrelation problems and to capture the dynamics effects following the Hanan and Quinn and Schwarz criterion. In all the cases only output, labor productivity and equipment investment are endogenous in their respective models.[68] In addition, the rank determination test and the roots of companion matrix allow us to detect two long-run relationships in all our estimated models.[69]

4. Empirical Results

Our results are presented in Tables 1-3; panel A of the tables is concerned with the long run relationships between the variables considered in each model, that is, the cointegrated vectors, and panel B shows the short run dynamics.

In Table 1 we present the coefficients estimated for the base models. Panel A describes how equipment investment, exports-to-GDP ratio and the real exchange rate account for labor productivity and output levels. The direction of the causality[70] run from equipment investment, exports and real exchange rate to output and labor productivity in the long-run. On the other

---

[68] See Table 2A.2 in the Appendix 2A
[69] See Tables 2A-3 to 2A-9 in the Appendix 2A
[70] The causality is assessed through significance tests on ECM parameters as it is possible to see in the dynamics of the models estimated.

hand, the second cointegrated vector shows a significant and positive impact of R&D expenditure on equipment investment. All the restrictions[71] imposed on these long-run relationships were accepted with a *p-value* of 0.097 for the productivity model and 0.617 and the output models respectively. Furthermore and in accordance with the battery of the stability tests[72], the concentrated model version seems reasonable stable. All coefficients show the expected signs and are significant.

Our findings are consistent with De Long and Summers (1991 and 1992), who argued that equipment investment is the main factor to promote output and labor productivity in the long-run among the components of investment and stressed the probable link between embodied technology and capital goods. It is only possible to find, this long-run effect, when the supply factors predominate among the determinants of investment such as technical changes. Chinese strategy has focused on the promotion of capital and intermediate goods imports for those production processes which are not possible to be produced themselves. It is expected that an embodied technological progress exists in these types of goods, which are imported from developed countries, and that it would be relatively cheaper, thus boosting both capital accumulation and its efficiency.[73]

An interesting result is that R&D expenditure stimulates equipment investment in the long-run in both models. This is consistent with Aghion and Howitt (1998, 1999) and with Howitt (2000) who argued that capital accumulation should be complementary with innovation activities both of which play a significant role in accounting for labor productivity and output in the long-run.

Additionally, and in line with other studies,[74] we found that exports and competitiveness (measured by the real exchange rate) positively affect on labor productivity and output in the long-run. This result is consistent with the export-led growth hypothesis. In fact, exports are

---

[71] We have imposed a restriction equal to zero on the coefficients of the variables that are not significant until the most irreducible form is reach. In all cases these restrictions are accepted as it is possible to see in the p-value that we report given that is over 0.05 in all the models estimated.
[72] Available upon request for all models estimated.
[73] See Lee (1995).
[74] See Shan and Sun (1998), Liu et al (1997 and 2002).

exogenous and cause output and labor productivity in the long-run and grew faster than economic activity.[75,76] These effects are related with an economic policy addressed to stimulate exports with the purpose of enhancing the level of activity and mitigate the foreign exchange constrain, thus making the aforementioned imports policy viable.

Table 1: Base Models: Output and labor productivity

A) Long-Run Relations[77]

		lprod	*lgdp*	*lifeq*	*lrd*	*xgdp*	*lrer*
Productivity Model	β'_1	1		-0.21 [-7.85]	0	-4.79 [-9.45]	-1.11 [-4.95]
	β'_2	0		1	-1.41 [-13.78]	0	0
GDP Model	β'_1		1	-0.13 [-2.92]	0	-1.50 [-2.83]	-1.25 [-4.57]
	β'_2		0	1	-1.39 [-13.99]	0	0

B) Dynamics of the base models[78]

	Δlprod	Δlifeq	Δlgdp	Δlifeq
$\Delta lprod_{t-1}$	0.33 (4.97)	-		
$\Delta lgdp_{t-1}$			0.34 (6.54)	-
$\Delta lifeq_{t-1}$	-	0.32 (5.35)	-	0.28 (5.65)
$\Delta lrer_{t-1}$	0.14 (2.60)	-	-	-
Δlrd	0.21 (10.3)	1.91 (9.95)	0.21 (9.05)	1.90 (9.78)
Δlrd_{t-1}	0.04 (2.41)	-	-	-
Δxgdp	0.26 (3.13)	-	0.21 (2.72)	-
$\Delta xgdp_{t-1}$	-0.45 (-4.01)	-	-0.18 (-2.16)	-
Constant	-0.56 (-7.35)	-0.54 (-5.03)	1.36 (9.57)	-0.58 (-4.81)
ΔD_{s85}	-	0.29 (3.03)	-	0.26 (3.54)
ΔD_{s85t-1}	-0.03 (-3.31)	-	-0.03 (-3.67)	-
ΔDs_{70t-1}	-0.09 (-4.82)	-0.84 (-4.56)	-0.05 (-2.29)	-0.78 (-4.24)
dum_{76p}	-0.07 (-7.43)	-	-0.06 (-7.13)	-
ecm_1	**-0.59** (-7.09)	-	**-1.78** (-9.80)	-
ecm_2	**-0.10** (-3.89)	**-1.24** (-4.89)	**0.14** (3.69)	**1.54** (4.68)
$\chi^2(16)$=16.434 (0.4231)		$\chi^2(18)$=24.092 (0.1520)		

[75] For a discussion on export-led growth in China see Bramall (2000).

[76] In the period 1962-1977 exports grew on average at a rate of 8.15%, while the average GDP growth rate was 7.04%. This difference is higher in the post-reform period (1978-2004) with an average growth rate of exports and GDP of 19.54% and 9.52% respectively.

[77] We show only the coefficients of the stochastic variables; the deterministic components are available upon request.

[78] Note: ecmi = $\beta'_i X_t$ + deterministic components and the t-value in brackets in all models in this paper

Table 1.B reports the dynamics of the base models. The labor productivity equation is error-correcting with the two cointegrated vectors found in the productivity model (β'_1 and β'_2). The alpha coefficient of the first long-run relationship, ecm_1, shows that the adjustment toward equilibrium is approximately a year and a half, while the alpha of the second relationship, ecm_2, shows that when investment is below its steady state, labor productivity undergoes a slight decrease. In the dynamics we find that labor productivity, R&D expenditure and the real exchange rate positively affect the labor productivity equation, while the net effect of exports is negative in the short-run. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector found in this model. The alpha coefficient indicates that the adjustment toward equilibrium takes place approximately less than a year. In the short-run, we find that R&D expenditure and the lag of equipment investment have a positive effect on the equation.

The output equation is error-correcting with the first cointegrated vector found in the output model and it adjusts toward equilibrium in almost seven months (ecm_1), while output increases when the equipment investment is above its steady state (ecm_2). In the dynamics, we find that R&D expenditure and the lag of output have a positive effect on output equation. Besides, the net effect of exports is positive in this equation. On the other hand, equipment investment overreacts with the second cointegrated vector found. As in consequence, we cannot interpret this equation in economic terms.

To address the robustness of our results, firstly we have included human capital, proxied by per capita years of schooling. The assumption is that more educated people are a good indicator of more skilled and more productive workers. It is expected that more skilled people would be more able to innovate, and to also make the absorption and adaptation of the new technology embodied in equipment investment easy, increasing additionally output and labor productivity.

In Table 2 we present the coefficients estimated for the augmented models with the human capital. The direction of the causality runs from equipment investment, exports, real exchange rate and human capital to output and labor productivity in the long-run. We find two cointegrated vectors for both labor productivity and output models, where all the restrictions were accepted with a *p-value* of 0.336 and 0.391, respectively. Our long-run relationships are reasonably stable in the concentrated model version, and the coefficients are significant with the expected sign.

These findings show that our conclusions on equipment investment and exports as sources of economic growth remain unchanged even for the inclusion of human capital, assessing its robustness. Of course, these same results suggest that investment and exports are not the only determinants of output and productivity in the long-run, but also human capital is a significant factor in determining the steady state of these variables, when equipment investment is considered. This finding is in agreement with, Greenwood et al. (1997), Temple and Voth (1998), Hendricks (2000) and Ortiguera (2003). Thus, output and labor productivity not only depend on equipment investment, but also on the technology absorption or on the adaptation through the worker's skill, and both factors are significant in the rapid Chinese development. Finally and similarly to the previous model estimated, we find that R&D expenditure encourages equipment investment in the long-run, run, but we did not find any direct impact of human capital on equipment investment. Therefore, new technologies open up new economic opportunities for equipment investment to take place in physical capital, and both, physical and human capital, encourage output and productivity.

Table 2.B reports the dynamics of the augmented model with human capital. The labor productivity equation is error-correcting with the two cointegrated vectors found in labor productivity model (β'_1 and β'_2). The alpha coefficient of the first long-run relation, ecm_1, shows that the adjustment toward equilibrium is a year and a half, while the alpha of the second relationship, ecm_2, shows a slight and negative effect on the labor productivity equation when equipment investment is below of it steady state. In the dynamics, we found that human capital, R&D expenditure and equipment investment have a positive effect on the labor productivity growth rate. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector (β'_2). The alpha coefficient of this long-run relationship, ecm_2, shows a rapid adjustment toward equilibrium at approximately four months. In the short-run, we find that human capital, R&D expenditure, and equipment investment have a positive effect on

this equation, while both labor productivity and the real exchange rate have a negative effect. Finally we find a net and positive effect of exports on the equipment investment equation.

Table 2: Augmented Models with Human Capital

A) Long-Run Relations

		lprod	*lgdp*	*lifeq*	*lrd*	*xgdp*	*Lrer*	*Δhc*
Productivity Model	β'₁	1		-0.17 [-4.27]	0	-4.06 [-5.10]	-1.95 [-6.37]	-0.62 [-2.57]
	β'₂	0		1	-1.06 [-3.99]	0	0	0
GDP Model	β'₁		1	-0.25 [-7.65]	0	-2.75 [-3.61]	-2.82 [-9.55]	-0.70 [-3.05]
	β'₂		0	1	-1.39 [-12.44]	0	0	0

B) Dynamics of Augmented Models with Human Capital

	Δlprod	Δlifeq	Δlgdp	Δlifeq
$\Delta lprod_{t-1}$	-	-2.82 (-4.31)		
$\Delta lgdp_{t-1}$			-	-1.40 (-2.85)
$\Delta lifeq_{t-1}$	0.09 (6.83)	1.01 (6.93)	0.04 (4.24)	0.55 (6.06)
Δlrer			-	-1.16 (-3.85)
$\Delta lrer_{t-1}$	-	-1.13 (-2.49)	-	-
Δlrd	0.15 (6.21)	1.33 (6.14)	0.20 (7.87)	1.70 (8.70)
$\Delta^2 hc$	0.09 (2.53)	-	-	-
$\Delta^2 hc_{t-1}$	-	0.70 (2.24)	-	1.01 (3.70)
Δxgdp	-	-2.24 (-3.35)	-	-
$\Delta xgdp_{t-1}$	-	2.70 (3.02)	-0.19 (-2.19)	-
Constant	-0.42 (-7.08)	-0.13 (-2.19)	0.68 (10.0)	-0.66 (-4.44)
ΔD_{s85}	-	0.26 (3.31)	-	0.29 (4.16)
ΔD_{s85t-1}	-0.04 (-4.46)	-	-	0.17 (2.49)
ΔDs_{70}	-0.09 (-3.16)	-0.69 (-2.67)	-	-
ΔD_{s70t-1}	-0.09 (-4.28)	-0.95 (-4.94)	-0.05 (-2.30)	-0.84 (-4.49)
dum_{76p}	-0.06 (-6.97)	-	-0.05 (-6.63)	- -
ecm_1	**-0.59** (-7.36)	**-**	**-0.73** (-10.5)	**-**
ecm_2	**-0.27** (-4.60)	**-2.80** (-5.69)	**-0.33** (-4.31)	**-3.09** (-5.20)
$\chi^2(16)=22.345\ (0.1324)$		$\chi^2(20)=23.142\ (0.2819)$		

The output equation is error-correcting with the two cointegrated vector found (β'_1 and β'_2). The alpha coefficient in the first long-run relationship, ecm_1, shows that the adjustment toward equilibrium is about nine months, while the second relation, ecm_2, shows a slight and negative effect on the output equation. In the dynamics we find that equipment investment and R&D expenditure have a positive effect on the output equation, while exports have a negative effect. The equipment investment equation is error-correcting with the second cointegrated vector. The alpha coefficient shows a rapid adjustment approximately less than three months. In the dynamics we find that equipment investment, R&D expenditure, human capital positively affect the equipment investment equation, while the lags of output and the real exchange rate have a negative effect.

Finally, we will take into account the role of infrastructures in this context. We took two indicators of infrastructure namely, passenger-km of highways and passenger-km of railways. These indicators are convenient given that they are associated with both infrastructure investment and demand. So, we could interpret this variable as a measure of the efficient use of the infrastructure. This issue is relevant in the Chinese economy because, during the pre-reform period, most infrastructure investment projects were finished and more investment was made than required. Since the seventies, however, a vastly demand of transportation system has taken place with a modest increase in new investments in infrastructures, which may only be account for by the more efficient use of the current transportation system.

In Table 3 we present the coefficients estimated for the augmented model with the infrastructures models. All the restrictions in the labor productivity model were accepted with a *p-value* of 0.05 when *lrprail* is included. The direction of the causality runs from equipment investment, exports and infrastructures to labor productivity in the long-run. However, we found no evidence when *lrphigh* was incorporated into this model. In the output model, all the restrictions were accepted with a *p-value* of 0.192 and 0.157 respectively, when the *lrprail* and *lrphigh* variables were included. The direction of the causality runs from equipment investment, exports, infrastructures and the real exchange rate[79] to output in the long-run. These long-run relations are reasonably stables in the concentrated model version and the coefficients are significant with the expected sign.

As in the case of human capital, when infrastructure is considered, the results obtained initially for exports and investment are maintained. So, even when we control our estimates for other relevant factors, such as human capital and infrastructures, we conclude that equipment investment and foreign trade polices have played a significant role in Chinese development in the last four decades. In addition, we provide evidence that infrastructure[80] enhances both labor productivity and output in the long-run. These findings are consistent with the relevant empirical literature mentioned before. Moreover, an interesting result is that both equipment investment and infrastructure promote labor productivity and output in the long-run, which shows there is some degree of complementary among them. Finally, in our model, R&D expenditure continues to be the only non-deterministic factor that stimulates equipment investment in the long run, without being detected any direct influence of infrastructures in that relationship.

Table 3.B describes the dynamics of the augmented model with infrastructures. The labor productivity equation is error-correcting with the two cointegrated vectors found in (β'_1 and β'_2). The alpha coefficient of the first long-run relationship, ecm_1, shows a fast adjustment toward equilibrium, at approximately six months, while the alpha of the second cointegrated vector adjusts toward equilibrium when labor productivity is below its steady state. In the dynamics we can observe no evidence of the congestion effect on infrastructure either in the short or long run. We found that infrastructure and equipment investment are significant factors in accounting for labor productivity in the short-run. Besides, R&D expenditure and the real exchange rate have a positive effect on labor productivity, unlike exports which present a net and negative effect on labor productivity. On the other hand, the equipment investment equation

[79] The real exchange rate causes output in the long-run only when *lrprail* is considered.

[80] We estimated infrastructures using a number of km of highways and railways. However, we did not find evidence of these infrastructure indicators on labor productivity and output in the long-run. It seems that not only the volume of investment but also the use of this type of investment are relevant. We do not report these estimates, but they are available upon request.

is error-correcting with the second cointegrated vector (β'_2). The alpha coefficient of this second long-run relation, ecm_2, shows that the adjustment toward equilibrium is approximately every year. In the dynamics, we find that R&D expenditure and the lag of equipment investment have a positive effect on this equation, while labor productivity shows a negative effect.

The first output equation is error-correcting with the two cointegrated vector found in the output model when *lrprail* is considered (β'_{11} and β'_{12}). The alpha coefficient of the first relation, ecm_1, shows a rapid adjustment toward equilibrium, while the alpha of the second relation, ecm_2 adjusts toward equilibrium when output is below its steady state. In the dynamics we find that R&D expenditure and equipment investment positively affects on the output equation, while exports have a negative effect in the short-run. On the other hand, the equipment investment equation is error-correcting with the second long-run relationship found (β'_{12}). The adjustment toward equilibrium is also very rapid. In the dynamics, we can observe that R&D expenditure and the own lag of equipment investment have a positive effect on equipment investment, while infrastructure and exports have a negative effect. Besides, the real exchange rate demonstrates that an increase (depreciation) tends to reduce equipment investment. It is possible to account for this effect given that many equipment and machinery are imported in China hence depreciation increases the price of imported goods. Finally, the lag of output has a negative effect on the equipment investment equation.

Table 3: Augmented Models with Infrastructures

A) Long-Run Relations

		lprod	*lgdp*	*lifeq*	*lrd*	*xgdp*	*lrer*	*lrphigh*	*lrprail*
Productivity Model	β'_1	1		-0.13 [-5..31]	0	-5.94 [-16.26]	0		-0.20 [-4.25]
	β'_2	0		1	-1.40 [-14.73]	0	0		0
GDP Models	β'_{11}		1	-0.20 [-5.88]	0	-3.98 [-6.39]	-1.04 [-2.80]		-0.45 [-3.61]
	β'_{12}		0	1	-1.44 [-14.93]	0	0		0
	β'_{21}		1	-0.18 [-3..33]	0	-4.99 [-8.11]	0	-0.83 [-5.68]	
	β'_{22}		0	1	-0.89 [-3..35]	0	0	0	

B) Dynamics of Augmented Models with Infrastructures

	Δlprod	Δlifeq	Δlgdp	Δlifeq	Δlgdp	Δlifeq
$\Delta lprod_{t-1}$	-	-2.36				
		(-3.67)				
$\Delta lgdp_{t-1}$			-	-2.37	-0.29	-1.76
				(-4.33)	(-2.59)	(-2.76)
$\Delta lifeq_{t-1}$	0.04	0.72	0.04	0.64	0.04	0.68
	(3.50)	(5.56)	(4.35)	(6.69)	(3.53)	(5.93)
Δlrer	-	-	-	-1.35	-0.14	-
				(-3.47)	(-2.36)	
$\Delta lrer_{t-1}$	0.27	-	-	-1.37	-	-
	(6.00)			(-3.44)		
Δlrd	0.20	1.78	0.21	1.60	0.23	1.40
	(9.36)	(8.68)	(8.55)	(8.23)	(9.35)	(7.12)
Δlrd_{t-1}	0.05	-	-	-	-	-
	(3.23)					
Δxgdp	0.37	-	-	-1.46	0.56	-
	(4.76)			(-1.90)	(4.37)	
$\Delta xgdp_{t-1}$	-0.75	-	-0.41	-	-0.43	-
	(-6.30)		(-3.60)		(-3.09)	
Δlrprail	-	-	-	-		
$\Delta lrprail_{t-1}$	0.12	-	-	-0.81		
	(5.16)			(-4.23)		
Δlrphigh					0.27	-
					(6.04)	
$\Delta lrphigh_{t-1}$					0.26	-
					(5.00)	
Constant	-0.89	-0.70	0.77	-0.69	0.81	-
	(-8.90)	(4.10)	(7.45)	(-4.77)	(8.11)	
ΔD_{s70}	-0.05	-0.41	-	-	-	-0.37
	(-1.95)	(-1.68)				(-1.80)
ΔD_{s70t-1}	-0.09	-0.95	-0.07	-0.80	-	-0.74
	(-3.99)	(-4.69)	(-3.23)	(-4.53)		(-4.84)
ΔD_{s85}	-	0.20	-	0.40	-	-
		(2.40)		(4.61)		
ΔD_{s85t-1}	-0.04	-	-0.05	-	-0.07	-
	(-4.81)		(-5.13)		(-4.82)	
dum_{76p}	-0.07	-	-0.07	-	-	-
	(-8.93)		(-7.57)			
dum_{89p}	-	-	-	-	-0.03	-
					(-2.58)	
ecm_1	**-1.73**	-	**-3.70**	-	**-2.25**	-
	(-8.79)		(-7.72)		(-7.97)	
ecm_2	**-0.08**	**-1.13**	**-0.22**	**-2.35**	**-0.19**	**-1.03**
	(-3.39)	(-4.77)	(-5.09)	(-6.59)	(-9.53)	(-5.25)
	$X^2(16)=25.049(0.0690)$		$X^2(18)=27.606\ (0.0683)$		$X^2(16)=24.132(0.0867)$	

The second output equation is error-correcting with the two cointegrated vectors found in the output model when *lrphigh* is considered (β'_{21} and β'_{22}). The alpha coefficient of the first relation, ecm_1, shows an adjustment towards equilibrium at approximately six months. In the dynamics we find that infrastructure, R&D expenditure and equipment investment have a positive effect on output equation, unlike the lag of output and the real exchange rate, which have a negative effect on this equation. Finally, the current value of exports has a positive effect, although its lag has a negative effect. On the other hand, the equipment investment equation is error-correcting with the second cointegrated vector found in (β'_{22}). The adjustment toward equilibrium is approximately a year. In the short-run we found that R&D expenditure and the lag of equipment investment have a positive effect on equipment the investment equation, unlike the lag of output which negatively affects this equation.

5. Conclusions

De Long and Summers (1991, 1992) emphasized the strong association of equipment investment and economic growth, especially in the case of developing countries which are not able to produce this type of goods themselves. These countries have to acquire most of their investment in machines and equipment in international trade through imports from advanced and intensive R&D countries. It is expected that embodied technological progress exists in this types of goods and cause long-run growth. Nonetheless, equipment investment is related with other important determinants of output and labor productivity such as human capital, infrastructures, R&D expenditure and openness among others. Human capital is a recurrent determinant of growth in the endogenous growth literature (Young, 1991; Romer, 1990; and Barro, 2001). This literature has also emphasized the substantial benefits from trade activity for example through economies of scale or to the access to advanced technology or spillovers. The expected role of infrastructures on growth changed following the empirical work by Aschauer (1989). Nowadays infrastructures are considered such as a source of externalities that stimulate output and productivity. Besides, the Schumpeterian version in the endogenous growth theory stresses the link between innovation activities and capital accumulation (Aghion and Howitt, 1998; Howitt, 2000). However, the empirical evidence of equipment investment and related variables is mixed; consequently, no conclusive results are found, especially regarding the direction of the causality of these factors on economic growth.

In this paper we have analyzed the role played by equipment investment as determinant of output and labor productivity in the short and long-run in China for the period 1962-2004. In addition, we have assessed its robustness in allowing for other relevant sources of economic growth such as R&D expenditure, human capital, exports and infrastructures.

Our findings suggest that equipment investment and exports are relevant factors to account for output and labor productivity in the long-run, even controlling for other sources of long-run growth in China for the period considered. Moreover, we found that the direction of the causality in all the models estimated runs from equipment investment and exports to output and labor productivity in the long-run. Besides, when human capital and infrastructures are included we found that these factors have also a positive effect on labor productivity and output, in the long run. A common result in all the models estimated is the positive effect of R&D expenditure on equipment investment in the long-run. Consequently, it seems that both capital accumulation and technical changes are significant for growth in the Chinese economy. Firstly, because we found that equipment investment and infrastructure have long-run effects and are likely due the embodied technological progress and the positive externalities. Secondly a significant effect of R&D expenditure on equipment investment is more plausible in some Schumpeterian version of endogenous growth theory than in traditional models of growth, especially for the case of China, which most of the equipment investment is imported from developed countries which are intensive in R&D activities. In this type of models capital accumulation and knowledge are complementary and play a critical role in the transition to long-run growth. Capital accumulation required new and advanced technology embodied in new investments, given the diminished returns of capital, and at the same time, new technologies need investments to implement them in the production process. Furthermore, the positive effect of human capital on labor productivity and output in the long-run is probably related with other forms of transmission of technology like absorption, adaptation or new inventions which cause long-run growth. Finally, the diffusion of the technology through international trade is one of the additional relevant mechanisms to promote labor productivity and output in the long-run.

Although it seems unquestionable the significant role of equipment investment, R&D expenditure, exports, human capital and infrastructures throughout the period under study we have to qualify our findings. Firstly, because equipment investment is mainly imported in the Chinese economy, hence the Chinese government has encouraged exports to finance the necessary imports. So, this factor of long-run growth depends on both capital imports and the foreign exchange constrains. Secondly, it is undeniable the positive effect of human capital in the transition process, however the level of the Chinese human capital is still far from other developing countries for instance India, South American economies etc. and back of the beyond of the technologically advanced countries. Besides, the Chinese government has tended to promote physical over human capital (Heckman, 2005). Hence, more reforms are needed in the education system to reduce the gap and to guarantee sustained growth. Finally, new investments and maintenance of the current infrastructures are necessary especially in central and western regions given the disparities among regions that exist in China.

In short, capital accumulation (physical and human) and exports has played a significant role in China in the period 1962-2004. The economic policies made by the government such as investment effort in infrastructures, promotion of equipment investment together with human capital and exports have apparently created the favorable conditions for long-run growth. Nevertheless, it is not sufficient condition to sustain long-run growth because more economic reforms are needed to benefit from balanced growth, not only in the sources of growth, but also among the different regions in the Chinese economy. Regardless of this argument, the Chinese economy currently is one of the most important economies in the world, where the most important aspect is that has successfully changed from a planned economy to a more market-economy, with improvements in labor productivity and output.

Appendix 2A

Table 2A.1: Unit Roots Tests

Variables	ADF		KPSS	
	const	trend	const	trend
lrprail	-0.84	-1.91	1.47*	0.19***
Δlrprail	-4.90*	-4.87*	0.18	0.12
lrphigh	-0.46	-1.36	1.49*	0.17**
Δlrphigh	-3.04*	-3.02*	0.18	0.18
lrer	-0.95	-1.40	1.42*	0.16**
Δlrer	-3.79	-3.80***	0.12	0.09
lrd	0.08	-3.53	1.40*	0.10
Δlrd	-5.86*	-5.88*	0.06	0.06
xgdp	1.49	-1.43	1.41*	0.27*
Δxgdp	-4.96*	-5.89*	0.49	0.06
lgdp	0.66	-2.81	1.49*	0.27*
Δlgdp	-6.31*	-6.40*	0.07	0.05
lprod	2.53	-1.79	-1.47*	0.34*
Δlprod	-4.35*	-5.72*	0.24	0.04
lifeq	-0.69	-6.65*	1.25*	0.03
Δlifeq	-8.34*	-8.24*	0.02	0.02
hc	-0.77	-2.64	1.53*	0.24*
Δhc	-2.62	-2.64	0.18	0.15**
Δ^2hc	-4.15*	-4.11*	0.06	0.06

* Rejection of the null at all the levels sign.
** Rejection at 5% and 10%
*** Rejection at 1%

Table 2A.2: Weakly Exogeneity Test

Vbles.	Model 1	Model 2	Model 1.1	Model 2.1	Model 1.2	Model 2.2	Model 2.3
lrer	0.06	0.50	0.07	0.05	0.13	0.81	0.64
xgdp	0.32	0.59	0.15	0.27	0.14	0.20	0.41
lrd	0.05	0.20	0.06	0.05	0.27	0.15	0.14
Δhc			0.26	0.51			
lrprail					0.06	0.05	
lrphigh							0.06

Model 1: Productivity Base Model
Model 2: Output Base Model
Model 1.1: Productivity Augmented Model with Human Capital
Model 2.1: Output Augmented Model with Human Capital
Model 1.2: Productivity Augmented Model with Infrastructure (rprail)
Model 2.2 Output Augmented Model with Infrastructure (rprail)
Model 2.3: Output Augmented Model with Infrastructure (rphigh)
Note: Under the null hypothesis of weakly exogeneity, this test is distributed as LR-Test, Chi-Square (r). P-values are in the Table.

Table 2A.3: Determination Rank Test and the Roots of the Companion Matrix
Productivity Base Model

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.72	79.55	70.53	49.46	0.000	0.000
1	1	0.50	28.07	23.11	25.61	0.024	0.097

	H(0)	H(1)	H(2)
Root1	1	1	**0.73**
Root2	1	0.77	0.71
Root3	0.47	0.30	0.71
Root4	0.06	0.12	0.16

Note: (*) corresponds to the trace test with Bartlett's correction. The asymptotic distributions have been simulated for the current deterministic specifications in all models using CATS in RATS.

Table 2A.4: Determination Rank Test and the Roots of the Companion Matrix
Output Base Model

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.64	60.19	54.24	40.87	0.000	0.001
1	1	0.38	19.35	17.63	20.81	0.080	0.129

	H(0)	H(1)	H(2)
Root1	1	1	**0.62**
Root2	1	0.59	0.62
Root3	0.34	0.30	0.47
Root4	0.04	0.30	0.47

Table 2A.5: Determination Rank Test and the Roots of the Companion Matrix
Productivity, Augmented Model with Human Capital

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.72	82.23	72.37	54.28	0.000	0.001
1	1	0.52	30.08	22.08	28.00	0.030	0.212

	H(0)	H(1)	H(2)
Root1	1	1	**0.67**
Root2	1	0.87	0.61
Root3	0.51	0.17	0.61
Root4	0.05	0.08	0.17

Table 2A.6: Determination Rank Test and the Roots of the Companion Matrix
Output, Augmented Model with Human Capital

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.73	82.96	75.17	53.90	0.000	0.000
1	1	0.52	30.12	23.59	27.41	0.027	0.146

	H(0)	H(1)	H(2)
Root1	1	1	**0.67**
Root2	1	0.84	0.63
Root3	0.31	0.13	0.63
Root4	0.02	0.13	0.02

Table 2A.7: Determination Rank Test and the Roots of the Companion Matrix
Productivity, Augmented Model with Infrastructure (rprail)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.70	72.16	63.95	43.77	0.000	0.000
1	1	0.45	23.89	20.90	23.00	0.036	0.086

	H(0)	H(1)	H(2)
Root1	1	1	**0.70**
Root2	1	0.67	0.51
Root3	0.47	0.38	0.51
Root4	0.06	0.08	0.07

Table 2A.8: Determination Rank Test and the Roots of the Companion Matrix
Output, Augmented Model with Infrastructure (rprail)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.66	64.28	58.02	44.59	0.000	0.002
1	1	0.40	20.97	19.38	22.45	0.080	0.123

	H(0)	H(1)	H(2)
Root1	1	1	**0.65**
Root2	1	0.64	0.43
Root3	0.34	0.14	0.43
Root4	0.01	0.07	0.29

Table 2A.9: Determination Rank Test and the Roots of the Companion Matrix
Output, Augmented Model with Infrastructure (rphigh)

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.79	74.54	68.82	49.92	0.000	0.000
1	1	0.26	12.16	10.75	26.68	0.739	0.827

	H(0)	H(1)	H(2)
Root1	1	1	**0.73**
Root2	1	0.64	0.73
Root3	0.20	0.51	0.52
Root4	0.20	0.51	0.52

Table 2A.10: Percentage of Equipment and
Machinery Imported to total Imports (average)

1950s	1960s	1970s	1980s	1990s	2000-2005
51%	20%	22%	25%*	39%	44%

* Only contains data for the years 1980-1985 and 1989, given the limitation of the data.
Source: Data from 1950-1984 was taken from Conroy (1986).
Data since 1985-2005 was taken from the NBS.

Measure of Human Capital

Human capital was taken from Wang and Yao (2003). These authors obtained a stock of human capital for each level of education as follows:

$$H_{1,t} = (1-\delta_t)H_{1,t-1} + (PRI_t - JUNIOR_{t+3})$$
$$H_{2,t} = (1-\delta_t)H_{2,t-1} + (JUNIOR_t - SENIOR_{t+3} - SPECIAL_{t+2})$$
$$H_{3,t} = (1-\delta_t)H_{3,t-1} + (SENIOR - HIGH_{t+3.5})$$
$$H_{4,t} = (1-\delta_t)H_{4,t-1} + (SPECIAL)_t$$
$$H_{5,t} = (1-\delta_t)H_{5,t-1} + HIGH_t$$

Where H_{ji} is the number of graduates with *j* the highest level of schooling attained in year *t*, *j*=1 for primary, 2 for junior secondary, 3 for senior secondary, 4 for specialized secondary, and 5 for tertiary. These authors consider that a person who did not complete the enrolled level *j* is considered *t* have completed the lower level of schooling (*j-1*). Given that the lengths of different schooling cycles are known the author calculate the net number of graduates at each level of schooling. In addition, δ_t is the mortality rate of the population in year *t* from the NBS. According with Wang and Yao (2003), the aggregate human capital stock is as follows:

$$H_t = {(5H_{1t} + 8H_{2t} + 11H_{3t} + 10H_{4t} + 14.5H_{5t})} \Big/ {Pop_t}$$

Where pop_t is the population in the age group 15-64 in year t. The initial value is 0.84 in 1951 based in India data of human capital (For further details see Wang and Yao, 2003). These authors cover the period 1952-1999. However the procedure employs futures value of each level of education and they do not hold data for these years. We have modified this measure by calculating a percentage of success for each level of education for the purpose of obtaining the number of graduates for the years that the data are missing in Wang and Yao (2003). We took the data from the NBS which covers the extended period of 1952-2004.

Appendix 2B

An Extension: Testing the Robustness of the effect of equipment investment on output.

The objective of this extension in our research has been to test the robustness of the effect of equipment investment on output in the Chinese economy over the period 1962-2004. In the Chinese statistics there are two definitions regarding investment: Gross Fixed Capital Formation and Fixed Assets Investment. Holz (2006) created two variables of investment in equipment using the data from the NBS, so-called in this analysis *equip1* and *equip2*, each of which is based on one of the definitions of investment used by the NBS respectively. Both are expressed in natural logarithms and in real terms, the investment price index being employed as a deflator. We estimated two different models, each of which uses one of the aforementioned variables for equipment investment to test its robustness. In addition, we incorporate into the model the foreign conditions measured by US GDP, exports, innovation activities, and competitiveness. [81]

We perform the analysis using the same methodology than in the previous study. However, we included in the analysis the causality test and Variance Decomposition to enrich the empirical results. First, in the same way than before, we tested the order of integration of our variables and second, we made all battery of miss-specification such as the residual analysis, selection of the lagged structure, the cointegration test and the stability tests.[82] The results are reported in Tables 2B.1-2B.3 in this Appendix.

Although we estimated our models with the two definitions of equipment investment, we found similar results, which show the robustness of our estimates. Our findings describe how output, equipment investment, exports and real exchange rate are cointegrated in (1) and (3) in Table 2B.1. The causality runs in one direction from equipment investment, exports and the real exchange rate to output in the long-run. On the other hand, the second relationship found in (2)

[81] For further details, see Holz (2006). According to the OECD Manual (2001), Fixed Assets Investment is the most appropriate measure of Capital Stock. For further details see Holz (2006). Base year 2000 = 100.

[82] These tests are not report here, and they are available upon request.

and (4) in Table 2B.1 proves that exports and R&D expenditure lead equipment investment in the long-run.

Table 2B.1 reports the dynamics of our estimated models, where all restrictions imposed were accepted.

Table 2B.1: Dynamics of Equipment Investment on output growth

	Model 1: Gross F. Inv. and Output		Model 2: Fixed Assets Inv. and Output.	
	Δlgdp	Δlequip1	Δlgdp	Δlequip2
$\Delta lgdp_{t-1}$	-	-1.25	-	-1.82
		(-3.98)		*(-3.13)*
$\Delta lequip1_{t-1}$	-	0.18		
		(3.28)		
Δlequip2			-	0.47
			-	*(5.65)*
Δlrer	-	-1.23	-0.15	-1.22
		(-5.49)	*(-2.08)*	*(-2.52)*
$\Delta lrer_{t-1}$	-0.22	-	-0.19	-
	(-3.48)		*(-2.87)*	-
Δlexp	0.11	0.48	0.14	0.43
	(5.00)	*(5.96)*	*(5.77)*	*(2.79)*
$\Delta lexp_{t-1}$	-	-0.64	-	-0.48
		(-7.97)	-	*(-3.71)*
Δlrd	0.17	1.41	0.21	1.66
	(9.53)	*(19.4)*	*(10.2)*	*(12.4)*
Δlrd_{t-1}	0.11	-	0.05	0.35
	(6.42)		*(2.47)*	*(2.01)*
$\Delta lgdpusa_{t-1}$	-	3.20	0.30	4.24
		(7.39)	*(2.19)*	*(4.72)*
Constant	1.88	-2.34	1.23	-2.70
	(11.6)	*(-14.9)*	*(8.10)*	*(-10.6)*
ΔD_{s70}	0.04	0.82	0.07	0.30
	(2.54)	*(11.6)*	*(3.62)*	*(2.23)*
ΔD_{s70t-1}	-	-0.31	-	-0.61
		(-5.32)	-	*(-6.05)*
ΔD_{s85}	-	0.08	-	0.27
		(1.72)	-	*(3.08)*
dum_{89p}	-	-0.28		
		(-5.94)		
dum_{76p}	-0.08	-		
	(-5.84)			
ecm_1	**-0.63**	-	**-0.64**	-
	(-11.2)		*(-9.62)*	-
ecm_2	-	**-1.35**	**-0.14**	**-2.79**
		(-14.8)	*(-3.60)*	*(-10.5)*
LR overiden. Rest. $\chi^2(17)$ = 26.445(0.0667)		LR overiden. Rest. $\chi^2(13)$ = 15.184 (0.2960)		

$$ecm_{11} = lgdp - 0.13\, lequip1 - 0.38\, l\exp - 1.10\, lrer + 0.23 D_{s85} \quad (1)$$

$$ecm_{21} = lequip1 - 1.95\, l\exp - 1.41\, lrd - 0.92 D_{s70} + 0.28t \quad (2)$$

$$ecm_{12} = lgdp - 0.19\, lequip2 - 0.31\, l\exp - 1.70\, lrer + 0.70 D_{s70} - 0.42 D_{s85} \quad (3)$$

$$ecm_{22} = lequip2 - 1.25\, l\exp - 1.22\, lrd - 0.94 D_{s70} - 0.38 D_{s85} + 0.16t \quad (4)$$

The GDP equation is error correcting with the long-run relationship found in (1) when Gross Fixed Capital Formation is considered and with (3) when Fixed Assets Investment is analysed. The alpha coefficient shows an adjustment towards equilibrium of approximately a year and a half in both models. In the short run, in the output equations we found common results, namely, exports and R&D expenditure have a positive effect, while the real exchange rate shows a negative effect. On the other hand, the equipment investment equation is error correcting with the long-run relation found in (2) for Gross Fixed Capital Formation and with (4) for Fixed Assets Investment. The alpha coefficients show a rapid adjustment towards equilibrium – less than a year for the model that contains Gross Fixed Capital Formation and less than six months for Fixed Assets Investment. In the dynamics we also found similar results in the equipment investment equations. R&D expenditure, the current value of exports, US GDP and the lag in equipment investment all have a positive effect on equipment investment. On the contrary, output, the lag of exports and the real exchange rate have a negative effect on equipment investment.

Table 2B.2: Causality test in the short and long run (statistics-value)

	Short-run Causality						***Long-run Causality***	
	Δlgdp	Δlequip1/Δlequip2	Δlrer	Δlexp	Δlrd	Δlgdpusa	ecm_1	ecm_2
Δlgdp	-	-	-3.48[a]	-5.00[a]	161.5*	-	-11.2[a]	-
Δlequip1	-3.98[a]	3.28[a]	-5.49[a]	82.60*	19.4[a]	7.39[a]	-	-14.8[a]
Δlgdp	-	-	14.04*	5.77[a]	138.71*	2.19[a]	-9.62[a]	-3.60
Δlequip2	-3.13[a]	5.65[a]	-2.52[a]	18.61*	200.8*	4.72[a]	-	-10.5[a]

Note: * shows the joint significance test distributed as χ^2 (2) derived from Table 1 and the subscript "a" shows the *t-statistic* from Table 1. The null hypothesis is that the variable analysed does not have an effect on its respective equation. All coefficients of our variables considered are significant and different from zero in their respective equation.

From Table 2B.1 it is possible to analyse the direction of the causality in the short and long run, given the significance of the coefficients. This information is summarised in Table 2B.2. The causality in the short run is examined by the joint significance of the lagged variables in the dynamics, while the causality in the long run is assessed by the significance of the error correction mechanism. The main findings derived from Table 2B.2 are that since exports, the real exchange rate and equipment investment enter into our first long-run relationship, we can conclude that these variables cause long-run effects on output. Furthermore, R&D expenditure and exports enter into the second long-run relationship and cause long-run effects on equipment investment. These findings can be seen in the highly significant statistic of the coefficient of the error correction mechanism in their respective equations. In addition, in the short run, the real exchange rate, exports and R&D expenditure cause output and all the variables analysed cause equipment investment.

Table 2B.3: Variance Decomposition of *lgdp*

Period	*lgdp*	*lequip1*	*lexp*	*lrd*	*lrer*	Period	*lgdp*	*lequip2*	*lexp*	*lrd*	*lrer*
1	100.00	0.00	0.00	0.00	0.00	1	100	0	0	0	0
2	85.37	0.24	1.05	13.18	0.16	2	82.75	0.01	3.74	13.49	0.01
3	69.40	4.54	3.69	22.24	0.14	3	59.11	6.40	12.34	21.23	0.92
4	50.37	26.67	4.85	18.00	0.11	4	41.52	24.26	14.87	16.86	2.49
5	**36.15**	**45.92**	**4.92**	**12.92**	**0.09**	**5**	**32.63**	**36.65**	**14.36**	**13.23**	**3.14**
6	30.52	53.24	5.54	10.62	0.08	6	31.04	39.59	14.71	11.73	2.93
7	28.71	54.30	6.74	10.18	0.07	7	31.71	37.30	15.91	12.50	2.57
8	26.97	54.12	7.87	10.97	0.07	8	30.76	34.73	17.12	15.02	2.37
9	25.17	54.74	8.41	11.57	0.11	9	29.32	33.88	17.42	17.06	2.31
10	**23.76**	**55.91**	**8.43**	**11.70**	**0.19**	**10**	**28.64**	**33.75**	**16.94**	**18.25**	**2.41**

Finally, in Table 2B.3 we show the forecast error variance of GDP, which is the proportion of the *h*-step forecast error variance of each variable considered in this study explained by each innovation. Thereby, the forecast error variance is decomposed into components accounted for by innovations in the different variables of the system. In accordance with this procedure, we can conclude that about 46% of the 5-step forecast error variance of GDP is accounted for by $equip_1$ innovations, and 5% by exports innovations, while if we consider a very long-term horizon, namely, a 10-step forecast error, about 56% of output is accounted for by $equip_1$ innovations and the figure drops to 8.5% in the case of export innovations. Similar conclusions can be drawn with the rest of the variables. This shows the relevance of equipment investment and its related variables in accounting for the process of China's growth.

References

Aghion P. and Howitt P., (1992). ‘A model of Growth through creative destruction’. *Econometrica* 60, pp.323-351

Aghion, P. Howitt, P., (1999). ‘Endogenous Growth Theory’. MIT Press, Cambridge, MA.

Aghion P. and Howitt P., (2007) ‘Capital, innovations and growth accounting’. *Oxford Review of Economic Policy* 23, pp.79-93.

An G. and Iyigun M.F., (2004). ‘The export technology content, learning by doing and specialization in foreign trade’. *Journal of International Economics* 64, pp.465-483.

Aschauer D.A., (1988). ‘Government Spending and the "falling rate" of profit’. *Journal of Economic Perspectives* 12 (May), pp.11-17

Aschauer D. A., (1989). ‘Is public expenditure productive?’ *Journal of Monetary Economics* 23, pp.177-200

Auerbach A.J., Hassett K.A. and Oliner S.D., (1994). ‘Reassessing the social returns to equipment investment’. *Quarterly Journal of Economics* 109, pp.789-802.

Baldwin R. E., (2003). ‘Openness and Growth: What’s the empirical relationship?’ NBER Working Paper No. 9578

Barro R., (2001). ‘Human Capital and Growth.’ *The American Economic Review* 91, pp.12-17.

Benhabib, J. and Spiegel, M. M., (1994). ‘The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country and Regional U.S. Data.’ *Journal of Monetary Economics*, 34, 2, pp.143–173.

Berglas E., (1965). ‘Investment and Technological change.’ *The Journal of Political Economy* 73, pp.173-180.

Bils M. and Klenow P., (2000). ‘Does schooling cause growth?’ *American Economic Review* 90, pp.1160-1183

Boileau M., (2002). ‘Trade in capital goods and investment-specific technical change.’ *Journal of Economic Dynamics and Control* 26, pp.963-984.

Borensztein E., De Gregorio J. and Lee J-W., (1998). ‘How does foreign direct investment affect economic growth?’ *Journal of International Economics* 45, pp.115-135.

Bramall C., (2000). ‘Sources of Chinese Economic Growth 1978-1996.’ Studies on Contemporary China. Oxford University Press.

Caballe J. and Santos M., (1993). ‘On Endogenous Growth with Physical and Human Capital.’ *The Journal of Political Economy* 101, pp.1042-1067

Canning D., Fay, M. and Perotti, R., (1994). ‘Infrastructure and growth’. In M. Baldassarri, L. Paganetto, & E.S. Phelps (Eds), International differences in growth rates. Great Britain: The Macmillan Press.

Caselli F. and Wilson D.J., (2004). ‘Importing technology.’ *Journal of monetary Economics* 51, pp.1-32.

Chow G., (1993). ‘Capital Formation and Economic Growth in China.’ *The Quarterly Journal of Economics* 108, pp.809-842

Chuang Y., (1997). ‘Learning by doing, the technology gap, and growth.’ *International Economic Review* 39, pp.697– 721

Dellas H. and Koubi V., (2001). ‘Industrial Employment, Investment Equipment, and Economic Growth’ *Economic Development and Cultural Change*, University of Chicago Press 49, pp. 867-881

De Long J.B. and Summers L.H., (1991). ‘Equipment Investment and Economic Growth’. *The Quarterly Journal of Economics* 106, pp.445-502

De Long J.B., Summers L.H and Abel A.B., (1992). ‘Equipment Investment and Economic Growth: How strong is the nexus?’ *Brookings Papers on Economic activity* 1992, pp.157-211

Démurger S., (2001). 'Infrastructure Development and economic growth: An explanation for regional disparities in China?' *Journal of Comparative Economics* 29, pp.95-117.

Devarajan S. Vinaya S. and Heng-fu Z., (1996). 'The composition of public expenditure and economic growth.' *Journal of Monetary Economics* 37, pp.313-344.

Eaton J. and Kortum S., (2001). 'Trade in capital goods.' *European Economic Review* 45, pp.1195-1235.

Eisner R., (1991). 'Infrastructure and Regional economic performance.' New England Economic Review, Federal Reserve Bank of Boston, September/October, pp.47-58.

Easterly W. and Rebelo S., (1993). 'Fiscal policy and economic growth.' *Journal of monetary Economics* 32, pp.417-458.

Esfahani H.S., (1991). 'Exports, Imports, and Economic Growth in Semi-Industrialized Countries.' *Journal of Development Economics* 35, pp.93-116.

Fan S. and Zhang X., (2004). 'Infrastructure and regional economic development in rural China.' *China Economic Review* 15, pp.203-214.

Feder G. (1983). 'On exports and economic growth.' *Journal of Development Economics* 12, pp.59-73

Fernald J. G., (1999). 'Roads to Prosperity? Assessing the link between pubic capital and productivity.' *The American Economic Review* 89, pp.619-638

Flores de Frutos A. and Pereira A., (1993). 'Public Capital and Aggregate Growth in the United States: Is Public Capital Productive?' U. of California at San Diego Discussion Paper pp.93-31

Frankel J. A. and Romer D., (1999). 'Does Trade Cause Growth?' *The American Economic Review* 89, pp.379-394

Garcia-Mila, T. McGuire T. J. and Porter R.H., (1996). 'The effect of public capital in state-level production functions reconsidered.' *The Review of Economics and Statistics* 78, pp.177-180.

Goh, A., Olivier, J., (2002). 'Learning by doing, trade in capital goods and growth.' *Journal of International Economics* 56 (2), pp.411 – 444.

Greenwood J., Hercowitz Z. and Krusell P., (1997). 'Long-run implications of investment-specific technological change.' *American economic review* 87, pp.342-362.

Griliches Z. and Jorgenson D.W., (1966). 'Sources of Measured productivity Change: Capital input.' *The American Economic Review* 56, pp.50-61.

Grossman G.M. and Helpman E., (1991). 'Innovation and Growth in the Global Economy' Cambridge, Massachusetts, MIT Press.

Heckman J., (2005). 'China's Human Capital Investment.' *China Economic Review* 16, pp.50-70

Helpman E., (1988). 'Growth Technological Progress and Trade.' *Empirica Austrian Economic Papers* 5, pp.5-25

Hendricks L., (2000). 'Equipment investment and growth in developing countries.' Journal *of Development Economics* 61, pp.335-364.

Herrerias MJ. and Orts V., (2009). 'Openness and Productivity in China.' In Z. Wu (ed.): *China in the World Economy*, Chapter 10. Routledge

Holz C., (2006). 'New Capital estimates for China.' *China economic review* 17, pp.142-85.

Holz C., (2006). 'Measuring Chinese Productivity Growth 1952-2005.' (July 22, 2006). Available at SSRN: http://ssrn.com/abstract=928568

Holtz-Eakin D., (1994). 'Public-sector capital and the productivity puzzle.' *The Review of Economics and Statistics* 76, pp.12-21.

Howitt P., (2000). 'Endogenous Growth and Cross-Country Income Differences.' *American Economic Review*, 90, pp.829- 846

Howitt P. and Aghion P., (1998). 'Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth' *Journal of Economic Growth* 3, pp.111-130

Hsiao .S.T. and Hsiao W., (2006). 'FDI, exports, and GDP in East and Southeast Asia—Panel data versus time-series causality analyses.' *Journal of Asian Economics* 17 (6), pp.1082-1106

Hulten C.R., (1992). 'Growth accounting when technical change is embodied in capital.'*American Economic Review* 82, pp.964-980.

Hulten C. R. Bennathan E. and Srinivasan S., (2006). 'Infrastructure, externalities and economic development: A study of Indian manufacturing industry.' *The World Bank Economic Review* 20, pp.291-308.

Johansen S., (1988). 'Statistical Analysis of Cointegration Vectors.' *Journal of Economic Dynamics and Control* 12, pp.231-254

Johansen S. And Juselius K., (1990). 'Maximum Likelihood Estimation and inference on cointegration-with Applications to the Demand for money.' *Oxford Bulletin of Economics and Statistics* 52, pp.169-210.

Johansen S.and Juselius K., (1994). 'Identification of the Long-run and the Short-run structure. An application to the ISLM model'. *Journal of Econometrics* 63, pp.7-36

Johansen S., (1995). 'Likelihood-Based inference in cointegrated vector auto-regressive models.' Advance Texts in Econometrics. Oxford University Press

Juselius K., (2007). 'The cointegrated VAR model: Econometric methodology and macroeconomics applications.' Oxford University Press

Juselius K. and MacDonald R., (2004). 'International parity relationships between the USA and Japan.' *Japan and the World economy* 16, pp.17-34.

Juselius K. and MacDonald R., (2000). 'International parity relationhips between Germany and the United States: A joint Modelling approach.' Working paper. Institute of Economics. University of Copenhagen

Kwan C.C.A., Wu Y. and Zhang J., (1999). 'Fixed Investment and Economic Growth in China'. *Economics of planning* 32, pp.67-79.

Lai M., Peng S. and Bao Q., (2006). 'Technology spillovers, absorptive capacity and economic growth.' *China Economic Review* 17, pp.300-320.

Lee J.W., (1995). 'Capital goods imports and long-run growth.' *Journal of Development Economics* 48, pp.91-110.

Levine R. and Renelt D., (1992). 'A sensitivity analysis of cross-country growth regressions.' *American Economic Review* 82, pp.942-963.

Liu X., Song, H. and Romilly P., (1997). 'An empirical investigation of the causal relationship between openness and economic growth in China'. *Applied Economics* 29, pp.1679-86

Liu X. Burridge P. and Sinclair P.J.N., (2002). 'Relationships between economic growth, foreign direct investment and trade: evidence from China.' *Applied Economics* 34, pp.1433-1440.

Liu Z., (2007). 'The external returns to education: Evidence from Chinese cities*.' Journal of Urban Economics* 61, pp.542-564.

Lopez R.A., (2005). 'Trade and Growth: Reconciling the Macroeconomic and Microeconomic Evidence.' *Journal of Economic Surveys* 19, pp.623-648

Lucas, R. E. JR., (1988). 'On the Mechanics of Economic Development.' *Journal of Monetary Economics*, 22, pp.3-42.

Madsen J.B., (2002). 'The causality between investment and economic growth.' *Economic Letters* 74 (2), pp.157-163.

Melitz M.J., (2003). 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica* 71, pp.1695-1725

Munnell A.H., (1990a). 'Why has productivity growth declined? Productivity and public investment.' New England Economic Review, (January/February), 3-22.

Munnell A.H., (1990b). 'How does public infrastructure affect regional economic performance?' New England Economic Review, (September/October), 11-32.

Munnell A.H., (1992). 'Policy Watch: Infrastructure Investment and economic growth.' *The Journal of Economic Perspectives* 6, pp.189-198.

Nelson R. and E. Phelps., (1966), 'Investment in humans, technological diffusion, and economic growth.' *American Economic Review* LVI, pp.69-75.

Nielsen H., (2004). 'Cointegration analysis in the presence of outliers.' *Econometrics Journal* 7, pp. 249-271

Ortiguera S., (2003). 'Equipment prices, human capital and economic growth.' *Journal of Economic Dynamic and Control* 28, pp.307-329.

Riezman R.G., Summers P.M. and Whiteman, C.H., (1996). 'The engine of Growth or its handmaiden? A time series assessment of export-led growth.' *Empirical Economics*. 21, 77-113.

Rivera-Batiz L.A. and Romer P.M., (1991). 'Economic Integration and Endogenous Growth.' *Quarterly Journal of Economics*, 106, pp.531-556.

Rodriguez F. and Rodrik D., (2001). 'Trade policy and economic growth: A skeptic's guide to the cross-national evidence' in B.S. Bernake and K. Rogoff (eds.) NBER Macroeconomics Annual 2000, The MIT press Cambridge.

Rodrik D., (1999). 'New Global Economics and Developing Countries: Making the Openness Work.' Policy Essay No. 24. Washington D.C. Overseas Development Council. Johns Hopkins University Press, Baltimore.

Röller L.H. and Waverman L., (2001). 'Telecommunications Infrastructure and economic development: A simultaneous approach.' *The American Economic Review* 91, pp.909-923

Romer P., (1990). 'Endogenous Technological Change.' *Journal of Political Economy* 98, pp.71-102

Sianesi B. and Reenen J.V., (2003). 'The returns to education: Macroeconomics.' *Journal of Economic Surveys* 17, pp.157-200.

Shan J. and Sun F., (1998). 'On the export-led growth hypothesis: the econometric evidence from China'. *Applied Economics* 30, pp.1055-1065

Siebert H., (2007). 'China: Coming to Grips with the new global player.' *The World Economy* 30, pp. 893 - 922

Temple J. and Voth H., (1998). 'Human capital, equipment investment, and industrialization'. *European Economic Review* 42, pp.1343-1362.

Uzawa H., (1965). 'Optimum Technical Change in an Aggregative Model of Economic Growth.' *International Economic Review* 6, pp.18-31.

Wang Y. and Yao Y., (2003). 'Sources of China's economic growth 1952-1999: incorporating human capital accumulation' *China Economic Review* 14, pp.32-52.

Young A., (1991). 'Learning by doing and the dynamics effects of international trade.' *The Quarterly Journal of Economics* 106, pp.369-405

Yu Q., (1998). 'Capital investment, international trade and economic growth in China: Evidence in the 1980-90s.' *China Economic Review* 9, pp. 73-84.

Yusuf S., (1994). 'China's Macroeconomic Performance and Management During Transition.' *The Journal of Economic Perspectives* 8, pp. 71-92

Chapter III

The Driving Forces behind China's Growth

3.1 Introduction

As stated by Jones (1995), the early AK-style models developed by Romer (1986), Lucas (1988) and Rebelo (1991), as well as the subsequent models of growth based on endogenous technical change such as those by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), suggested that investment, defined in a broad sense, has permanent effects on the growth rate of the economy and can also improve the long-run path of productivity growth through learning-by-doing and technology spillovers. However, this relationship between investment and growth has become one of the most controversial issues in the empirical literature. Thus, Jones (1995) did not find evidence of permanent effects of investment on economic growth, a result which rejected the main implications of endogenous growth models and supported Solow's view of growth. Furthermore, Blostöm et al. (1996) found that the strong relationship between investment shares of GDP and growth were due more to the effect of growth on capital formation than to the effect of capital formation on growth. These findings have led to doubts about the validity of such models as an alternative to the Solow framework and therefore the relationship between investment and other policy variables and growth. This issue has since been reviewed several times in the literature from both a theoretical and an empirical point of view. From a theoretical perspective, the Schumpeterian version of the endogenous growth theory, developed by Howitt and Aghion (1998) among others, stands out above the rest. In this approach, capital accumulation and innovation activities determine the rate of growth and have permanent effects on the rate of productivity growth, due to the embodied technological progress. Similarly, and from an empirical point of view, using more sophisticated econometric techniques, some authors have recently found evidence of a positive relationship between investment and growth (Bernanke and Gürkaynak, 2001; Li, 2002; Bond et al., 2004).

In this context, the Chinese economy, which has been characterized by high growth rates for almost four decades and high rates of capital accumulation, represents an interesting case with which to analyse this relationship. Additionally, testing for the existence of a long-term relationship between the two magnitudes, together with other relevant sources of growth emphasized by endogenous growth models, can help us to discriminate between the driving forces behind China's growth. At the same time, it can help clarify whether it has only been the result of a process of factor accumulation or if, on the contrary, this factor accumulation has co-existed with significant endogenous technological progress. From this perspective, some authors such as Chow (1993) and Woo (1998) argued that the rapid growth of China is mainly due to the injection of productive factors, without technological progress playing any significant role. These authors consider that the pattern of growth of China is similar to that experienced by East Asian countries in the sixties. In those cases, economic growth was stimulated mainly by capital accumulation and, consequently, the high rates initially displayed by these economies turn into "normal rates" after a period of time and have just a transitory effect on the growth rate (Krugman, 1994; Young, 1995).

However, from the perspective of the endogenous growth models, the influence of the accumulation of capital, along with other additional elements such as openness, innovation activities, investment in human capital and so on, are capable of generating sustained efficiency gains and growth in the long run. The debate is interesting, both from the standpoint of analysing the nature (permanent or transitory) of the effects of these factors on the growth rate of output and productivity, and from their implications for the sustainability of growth and for the design of appropriate economic policies. For instance, should China pursue outward- or inward-oriented policies? Is capital accumulation a suitable strategy to sustain high growth rates? Do innovation activities influence the long-run rate of economic growth? Could competitive exchange rates and other government policies promote growth in the long run? If this is the case, is there a causal relationship among these determinants and economic growth?

To address these questions, economists have focused on diverse theoretical frameworks and have used different empirical methodologies, with very mixed results. As a consequence the sources and nature of Chinese growth remain an open question. This study attempts to make a contribution in this strand of the literature. In particular, the purpose of this paper is to analyse the link between investment and growth and their interactions with other sources of economic growth like openness to trade, R&D expenditure, human capital and competitiveness, in both the short and the long run in China from 1965 to 2000. Thus, in our empirical analysis we have two complementary focal points of interest. First, we analyse the statistical properties of labour productivity and output growth series with an extended battery of unit root tests. We begin by re-examining this issue because it has relevant implications in both the inference in time series analysis and in economic growth analysis. In fact, one of the main arguments against endogenous growth is based on the stationarity of growth rates.[83] And second, in order to avoid the main modelling problems in time series analysis (stochastic trends in the variables and potentially endogenous regressors) and given the established links between cointegration and endogenous growth models,[84] we use the cointegrated VAR methodology to analyse the short- and long-run relationships among the different potential determinants of growth and output and productivity growth rates. In addition, since we know that China's economy has been immersed within a set of continuous shocks and transformations, we have introduced different structural breaks, which allow us to guarantee the stability of our long-run relations. The econometric results provide robust evidence that capital accumulation, in a broad sense (physical and human

[83] See for example Jones (1995) or Kocherlakota and Yi (1997).
[84] See for example Lau and Sin (1997) and Lau (1999).

capital), innovation activities (R&D), and openness to trade (exports and imports) have been the main factors which determine the long-run growth of labour productivity and output in China. Finally, we found some evidence that the sustained high real exchange rate also played a significant role in explaining the growth of output and labour productivity in the period considered. Thus, these results are more consistent with some versions of the endogenous growth theory than with Solow's model of growth.

The rest of the paper is set out as follows. In Section 2 we present a literature overview and outline a theoretical model to illustrate our empirical analysis. Section 3 contains the description of the variables that were considered and the strategy of the empirical analysis and model specification. Finally, the main results are shown in Section 4 and Section 5 includes the conclusions that were drawn.

3.2 An Overview of the Literature

One aspect that is common to all the theoretical literature on economic growth, from the Solow textbook model to the more recent endogenous models developed by Romer (1986, 1990), Lucas (1988), Grossman and Helpman (1991), Rebelo (1991), Aghion and Howitt (1992) or Howitt and Aghion (1998) among others, has been to highlight the contribution of the accumulation of productive factors, especially physical and human capital, and technological progress in explaining economic growth. In this literature, capital accumulation has played a central role and these developments have logically been reflected in the aims of empirical work. Thus, a lot of empirical literature has focused on the effect of capital accumulation on growth, but with mixed results. While the aforementioned papers by Jones (1995) or Bloström et al. (1996), among others, do not find evidence of permanent effects of investment on economic growth, in more recent contributions by Bernanke and Gürkaynak (2001), Li (2002) or Bond et al. (2004), some evidence of a positive relationship between investment and growth does seem to emerge. Similarly, and in addition to physical capital, human capital has also been considered a fundamental factor in determining long-run growth rate in the literature (Lucas, 1988; Barro, 2001). More highly skilled workers could facilitate the introduction of larger amounts of new, better quality varieties of intermediate goods and could increase the productivity of physical capital through specialization and by improving the learning-by-doing mechanism, thus raising efficiency and productivity. In addition, education acts as a factor of production, either directly by stimulating the development of new technologies or through facilitating technology use, adaptation or imitation, thereby avoiding the threshold limitation that human capital imposes on the technological absorptive capability of developing countries (Borensztein et al., 1998; Bils and Klenow, 2000; Benhabib and Spiegel, 2005). Finally, there are externalities associated with better-educated people that can positively affect long-run growth rates (Sianesi and Reenen, 2003).

However, one of the main issues on which some discrepancy persists in this field is whether these factors can or cannot have permanent effects on growth in the long run. This controversy is easily illustrated with a standard growth model. Consider the following human capital augmented Solow-type model: the production function with constant returns to scale and decreasing returns to reproducible factors can be written as:

$$Y_t = K_t^{\alpha} H_t^{\beta} \left(A_t L_t \right)^{1-\alpha-\beta}$$

where *Y* is output, *K* and *H* are physical and human capital respectively, *L* is labour and *A* is labour augmenting technological progress, and $0 < \alpha + \beta < 1$. This production function can be expressed in intensive terms as:

$$y_t = k_t^{\alpha} h_t^{\beta} \qquad (1)$$

where *y, k and h* are the output level and the stocks of physical and human capital expressed in intensive terms, that is, $y = Y/AL$, $k = K/AL$ and $h = H/AL$. From (1) it is clear that, as a whole, the production function under consideration exhibits decreasing returns to capital.

Assuming that i_k an i_h, are the constant investment rates in physical and human capital, that both types of capital depreciate at the common rate δ, and that *L* and *A* grow exogenously at rates *n* and *a* respectively, the time paths of the variables involved in (1) are given by:

$$\dot{k} = i_k y - (a + n + \delta)k \qquad (2)$$

$$\dot{h} = i_h y - (a + n + \delta)h \qquad (3)$$

$$\dot{\mathrm{A}} = a\mathrm{A} \qquad (4)$$

$$\dot{\mathrm{L}} = n\mathrm{L} \qquad (5)$$

Given the existence of decreasing returns on reproducible factors, the long-run steady state of the model can be found by solving (1) to (5) for $\dot{k} = \dot{h}$ =0, so that:

$$k = \left(\frac{i_h^{\beta}\ i_k^{1-\beta}}{a + n + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \qquad (6)$$

$$h = \frac{i_h}{i_k} k \qquad (7)$$

$$y = \frac{a + n + \delta}{i_k} k \qquad (8)$$

Expressions (6) to (8) define the constant steady-state level of physical capital stock, human capital and output per worker in intensive terms. From these expressions it is straightforward to see the standard textbook result of Solow-type growth models, which is that in the steady state the growth in the rate of output per worker (*g*) is determined by the rate of exogenous technological progress, without any influence of structural parameters such as investment rates; that is:

$$g = a \qquad (9)$$

The empirical implication of (9), in Jones's (1995) words, is that the "level of output is fit well by a growth process with a constant mean … and very little persistence".[85] This

[85] Jones (1995), pp. 498-499.

implication is in sharp contrast with the empirical implications of the endogenous growth models.

Consider now that in the preceding model $\beta = 1 - \alpha$; in this context the model exhibits constant returns to capital as a whole, and this is enough to generate endogenous growth. Solving the model again, it is easy to see that the relationship between *h* and *k* remains constant and equal to $(1-\alpha)/\alpha$, and *y* can be expressed as a function of *k*:

$$y_t = \left(\frac{1-\alpha}{\alpha}\right)^{(1-\alpha)} k_t$$

Now, however, *h* and *k* do not remain constant in the long-run steady state, instead they just grow at the same rate. Consequently, the steady state cannot be established in terms of the variables in levels but in growth rates; and the steady-state growth rate of output per worker can be expressed as a function of physical capital accumulation, that is:

$$g_t = a + \Delta k_t / k_t \qquad (10)$$

Thus, the endogenous growth models stressed the link between capital accumulation, in a broad sense, and growth, in opposition to the point of view of Solow-type models, where the main driver of steady-state economic growth is just the exogenous technological progress. Additionally, while the AK models like the one we have just outlined stressed the role played by capital accumulation in growth, the endogenous technological change models developed by Romer (1990), Grossman and Helpman (1991) or Aghion and Howitt (1992), among others, emphasized the contribution of innovation activities to economic growth and well-being. Finally, the Schumpeterian version of endogenous growth, developed by Aghion and Howitt (1998) among others,[86] extended the preceding models to integrate both determinants and stressed the complementarities between physical and human capital accumulation and technological change as the main mechanism driving growth performance and permanent

[86] Howitt and Aghion (1998) review the endogenous literature from this perspective.

increases in the growth of productivity. In sum, as stated by Jones (1995): "a hallmark of the endogenous growth literature is that permanent changes in variables that are potentially affected by government policy lead to permanent changes in the growth rates".[87]

It is also clear that the new growth theory grants other factors an important role as determinants of the steady-state growth rates. From our point of view, openness is among the most extensively addressed topics in economic growth and development and is a key factor in the recent development of the Chinese economy. There is growing agreement that both trade policies and higher trade volumes to GDP ratios are positively correlated with growth, even after controlling for a variety of other factors of growth (Wacziarg, 2001).[88] Openness to international trade is associated with different international research and development spillovers that positively affect long-run growth (Coe and Helpman, 1995). From the point of view of developing countries, openness to international trade offers attractive chances to acquire capital goods from abroad. These goods are often imported by developing countries from technologically advanced countries, thus facilitating the access of developing countries to relatively cheaper and technologically intensive capital goods (Lee, 1995; Mazumdar, 2001; Eaton and Kortum, 2001).[89] Moreover, the effort made in innovation based on imported technologies can be a precursor to the development of domestic innovation capabilities (Mody and Yilmaz, 2002). Finally, access to intermediate inputs, as regards both quantity and variety, is an additional mechanism to enhance long-run growth, since it affords domestic producers greater access to new innovations or imitations of new products (Grossman and Helpman, 1991; Broda and Weinstein, 2004).

In a similar way, exports are also considered to be a source of positive spillovers and efficiency gains. At first, the self-selection of firms that induces openness to trade improves the economy's productivity (Melitz, 2003). Export activity can, however, further increase the

---

[87] Jones (1995), p. 495.
[88] But growing consensus it is not the same as unanimity, and there are also some critics to this view. Thus, some author like Rodrik (1995 and 1999) or Rodriguez and Rodrik (2001), among others, observed that countries whose incomes are high for reasons other than trade may also trade more.
[89] A recent review of the literature showed that the positive effects of trade liberalization can be found in Baldwin (2003) and Greenaway and Kneller (2007).

relative productivity of exporting firms compared with that of businesses which only operate in the domestic market. This is due to the learning process associated with the acquisition of different types of knowledge from their international contacts (new methods of production and organizational style, better product designs, and so on) (Chuang, 1998; Clerides et al., 1998). This may also be due to the exploitation of the economies of scale that access to international trade allows (Helpman and Krugman, 1985). Moreover, exporting activity allows foreign exchange constraints to be relaxed, thus permitting increased imports of capital and intermediate goods (Esfahani, 1991; Riezman et al., 1996).

Additionally, in an open economy there is a close relationship between trade, investment, and economic development. There is empirical evidence to suggest that the effects of openness to international trade on economic growth are mediated largely by the rate of physical capital investment (Levine and Renelt, 1992; Baldwin and Seghezza, 1996; Wacziarg, 2001). An alternative point of view is to be found in Rodrik (1995), who suggests that exports, in the case of East Asian countries for example, may have been driven by an increase in the profitability of investment, with outward-oriented policies being a consequence of the investment boom rather than its instigator. Finally, and especially for developing countries, there is another factor that could influence the relationship between outward orientation and economic growth, i.e. the level of real exchange rate. Although the empirical evidence on the issue is also mixed and there is a significant body of empirical work which does not support the positive relationship between a sustained competitive currency and growth (Easterly, 2005; Acemoglu et al., 2003), in two recent papers by Gala (2007) and Rodrik (2008) evidence is provided to show that undervalued currencies (higher real exchange rates) stimulate growth. Specifically, Gala (2007) shows that maintaining a competitive exchange rate has been a key factor in most successful growth strategies in East and Southeast Asia in the last 30 years. Rodrik (2008), on the other hand, extends this evidence to a significant panel of developing countries, the channel through which this effect operates being the size of the tradable sector (especially industry).

In the case of China, economists have focused on diverse theoretical frameworks to analyse the deeper determinants of economic growth, and have used different empirical methodologies and data at different levels of aggregation to address these issues. For example, some papers have used stochastic frontier production function approaches and non-parametric techniques at the national, provincial or industry level to assess the contribution of productive factors, improvements in efficiency and technological progress on productivity (Wu, 2000; Chen, 2003; Zheng et al., 2008, among others). Although these studies conclude that physical capital accumulation and technological progress have played a significant role in the post-reform period in China, they cannot distinguish what factors are responsible for the efficiency gains. In several different studies in which traditional econometric methods were employed, Chow (Chow, 1993; Chow and Lin, 2002; Chow, 2008) found that technological progress was absent during the pre-reform period, and total factor productivity (proxied by a deterministic linear trend) only increased sharply during the post-reform period. However, questions such as the non-stationarity of the variables, endogeneity and the direction of the causality between the potential determinants of China's growth are not considered, and the researcher relies on an exogenous growth framework.

Few empirical efforts have been made to simultaneously consider the aforementioned questions, which are especially relevant in time series analysis. Nevertheless, there are some exceptions. For example, Yu (1998) employed the Engle and Granger two-step estimator, over the period 1980 to 1990, and found that exports and investment explained output growth, while imports did not contribute to economic performance. In a time series approach using data from 1952 to 1993, Kwan et al. (1999) estimated equation by equation and found empirical evidence on the contribution of investment and exports to growth, exports being consistent with large increases in investment. In contrast, Qin et al. (2005) estimated a VAR model for the period 1993-2003, finding empirical evidence that the causation runs from output to investment. However, none of these authors consider the importance of human capital or innovation activities, or the potential interdependence between economic growth and its determinants, which suggests a joint modelling with the possibility of multiple cointegrating relations. Only the last work considers the endogeneity of investment, but in a bivariate analysis which could give rise to bias due to the omission of other relevant variables. On the other hand, Liu et al.

(1997 and 2002), Jin (2004) and Yao (2006) find a positive relationship between exports and growth, while Fu (2005) argued that no evidence was found to suggest significant productivity gains at industrial level as a result of expanding exports. Finally, Hsiao and Hsiao (2006), using different empirical specifications, found that exports do not cause growth at all.[90] Thus, the empirical evidence between growth, investment and exports seems mixed and surprisingly we did not find any empirical evidence supporting the notion of imports as an additional source of growth (as the endogenous growth models emphasize) for the case of China.

In contrast, in the papers that have focused on human capital in China, we did find a positive relationship between human capital and growth (Chen and Fleisher, 1996; Chi, 2008). Often these analyses are applied at regional level, probably due to a lack of data. In addition, in a study using growth accounting methods, Wang and Yao (2003) emphasized the relevance of human capital on growth at the national level from 1952 to 1999. However, their method does not allow casual relations to be established among the variables of interest and this is one of the goals of this paper.

Finally, as far as we know, there is no empirical evidence on the relationship between real exchange rate and growth in the case of China, besides the fact that it has been qualified by Rodrik (2008) as "the most fascinating (and globally significant) case" of association between undervaluation and growth. In recent decades, China has undergone a rapid increase in economic growth, and also international trade, and simultaneously the position of the Renminbi has changed "from an overvaluation close to 100 percent to an undervaluation of around 50 percent".[91] Two interesting questions, both from the point of view of their implications in the sources and structural effects of Chinese growth and from the perspective of their implications in economic policy, need answering here: (1) To what extent has the increase in the commercial flows been among the causes of Chinese growth? Or, on the contrary, (2) Has such a large part of its commercial expansion and increased growth resulted simultaneously from a policy of

[90] These studies neglect the role of human capital and innovation activities.

[91] Rodrik (2008), p. 3. We can see similar results on real exchange rate misalignment in China in Zhang (2001). A detailed analysis and chronology of exchange rate policy in China can be found in Lin and Schramm (2003).

undervaluing the exchange rate? Thus, one of the objectives of the paper is to unravel the extent to which depreciation of the real exchange rate is important for Chinese growth.

3.3 A Time Series Analysis of Chinese Growth

In the empirical analysis we used annual data from 1965 to 2000 on Chinese output (GDP) and labour productivity (output per worker) growth rates, jointly with the rate of physical capital accumulation, human capital accumulation, R&D expenditure,[92] three alternative variables of openness to trade (exports-to-GDP ratio, imports-to-GDP ratio or trade-to-GDP ratio), and the real exchange rate.[93] All the variables in levels are expressed in real terms[94] and in natural logarithms (except the ratio of exports, imports or trade to GDP and the human capital). Our data source was the National Bureau of Statistics of China (NBS),[95] except for the stock of physical and human capital. The stock of physical capital was taken from Wu (2004) and the stock of human capital from Wang and Yao (2003).[96]

Our empirical strategy to test the relevance of endogenous growth models and their implications in the case of China has two steps. First, we analyse the persistence of changes in its growth rate using different methods to test for the level of integration of time series growth rates. And second, we test whether permanent changes in the rate of capital accumulation, together with the other relevant sources of growth mentioned above, have permanent effects on the growth rates. To do this, and taking into account the stochastic properties of data and the potential endogeneity among the variables that were considered, we examined the existence of long-run relationships using the cointegrated VAR methodology.

The former step is relevant for at least two reasons. The first is that time series properties of growth rates can provide important information regarding the relevance of different growth

[92] We took total expenditure on scientific research from the NBS as a proxy variable of R&D expenditure.
[93] The real exchange rate was calculated using the nominal exchange rate between the Chinese currency and the US $ (Renminbi/$) and the respective consumer price indices (CPIs).
[94] We have deflated R&D expenditure with the GDP deflator.
[95] Although there is some controversy regarding the quality of Chinese statistics, there does seem to be some agreement on their viability for examining long-term trends. See Holz (2005), Chow (2006) and Bai et al., (2006).
[96] We have updated Wang and Yao's (2003) measure of human capital stock from 1995 to 2000. Further details about the updating are available from the authors on request.

models over the period under consideration. The second reason is that the trending properties of the variables determine the models and inference procedure to be used in the later stages of the empirical analysis. The second step, however, could help us to understand the potential factors that drive China's economic growth, and could therefore aid policymakers in addressing the appropriate economic policies in China.

a) Unit Root Tests

Many papers have used the traditional Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests and found that the levels of output or labour productivity are integrated of order one and their growth rates are stationary, exhibiting little or no persistence; yet, little empirical evidence seems to exist that employs alternative tests to improve the model specification and the inference for the case of China. However, looking at their graphs,[97] there is a suspicion that the level of GDP and labour productivity could be integrated of order two. This possibility could probably be explained by two facts: the negative shocks experienced by the Chinese economy during the 1960s and 1970s and its rapid growth in the last two decades. Nevertheless, given the relevance of distinguishing between growth rates generated by a unit root process from growth rates with some persistence but mean reverting, we are going to re-examine this issue more closely.

Although the ADF and Phillips-Perron test are the most commonly used methods to test for the presence of unit roots, many researchers remain sceptical about the results from these standard unit root tests, and it is well known that "these tests generally suffer from two problems. First, many tests have low power when the root of the autoregressive polynomial is close to but less than unity. Second, the majority of tests suffer from severe size distortions when the moving-average polynomial of the first differenced series has a large negative root."[98] The consequence is over-rejection of the unit root hypothesis. Thus, we are going to use additional tests for unit roots with the aim of mitigating these problems. First, we use the test

[97] Available upon request.
[98] Ng and Perron (2001), pp. 1519-1520.

suggested by Kwiatkowski et al. (1992). This test reverses the hypothesis of traditional tests, assuming that under the null hypothesis the time series are stationary. Second, following Ng and Perron (2001), we use their much larger and more powerful unit root test (M tests) to overcome the lower power of traditional tests due to size distortions, as well as to provide a more adequate selection of lag length. Ng and Perron (2001) developed a unit root test based on GLS detrending in order to achieve substantial power gains, which allow a more precise autoregressive spectral density estimator, provided that the truncation lag is selected appropriately. These authors suggested a Modified AIC rule to select the truncation lag instead of the more usual AIC rule, which tends to select a lag length that is too small, due to its under-estimating the cost of a low-order model in several circumstances.[99] Finally, as is argued in Lanne and Lütkepohl (2002) and Lanne et al. (2002), it is also known that the standard unit root tests have reduced power if they are applied to time series with structural shifts. Thus, building on a proposal by Saikkonen and Lütkepohl (2001), Lanne et al. (2002) developed a unit root test to deal with very general non-linear deterministic shift functions. Additionally, the estimation of deterministic terms by a GLS procedure is also considered. The simulations carried out by these authors showed that tests which estimate the deterministic term by a GLS procedure under the unit root null hypothesis are also superior in terms of size and power properties compared to tests which estimate the deterministic term by OLS procedures.

In Table 1 we present the summary of results from our analysis of the GDP and labour productivity time series properties using the five aforementioned unit root tests, with different determinist terms (none, constant and constant with trend). These tests are the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), the test developed by Kwiatkowski et al. (1992) (KPSS), the Ng and Perron (2001) test, and the unit root test with breaks developed by Lanne et al. (2002) (LLS).

[99] Perron and Ng (1996) showed that the M tests have dramatically smaller distortions than most (if not all) unit root tests in the literature in cases of negative moving-average errors if the autoregressive spectral density estimators defined above are used in conjunction with a suitably chosen k.

The results presented in Table 1 can be described as mixed.[100] In both cases we reject the null of unit root in the GDP and labour productivity growth rates when the constant and constant with trend are included, at all levels of significance, according to the ADF and PP tests. However, with the KPSS test we reject the null that time series growth rates of GDP and labour productivity are stationary, and according to Ng and Perron and the LLS tests it is not possible to reject the null of unit root in growth rates.[101] Thus, although the issue of the order of integration should be examined more carefully due the continuous efforts made to develop new tests, it is possible to think that the tests developed by Ng and Perron (2001) and Lanne et al. (2002) are the ones with the most precise power compared with the others used in this paper. We conclude that both series can be characterized as being integrated of order one.

Table 1: Unit Root Tests (Value of test statistic)

	ADF Test			Phillips-Perron Test			KPSS Test	
	Null: Unit Root			Null: Unit Root			Null: Stationary	
	none	const.	trend	none	const.	trend	const.	trend
Δlgdp	-1.37	-6.62 *	-6.70 *	-2.25**	-8.10*	-8.26*	0.50**	0.36*
Δlprod	-0.72	-5.39*	-5.98 *	-3.66*	-4.33*	-7.31*	0.43*	0.50*

	Ng-Perron Test						LLS Test	
	Null: Unit Root						Null: Unit Root	
	Constant			Trend				
	MZ_α	MZ_t	MSB	MZ_α	MZ_t	MSB	None	trend
Δlgdp	-2.17	-0.95	0.44	-11.51	-2.39	0.20	-2.36	-2.57
Δlprod	-1.41	-0.74	0.53	-17.00*	-2.91*	0.17*	-1.64	-2.17

Note: The tests were performed with Eviews and JMULTI. * Rejection of the null at 10%, ** Rejection of the null at 5%, *** Rejection of the null at 1%.

Finally, although we accept that the growth rates of output or labour productivity are integrated of order one, this property would only be compatible with models of endogenous growth if the variables that are potential determinants of growth were also integrated of order one and there is a cointegration relationship between them.

[100] We also performed the stationary test implemented in CAT for RATS, and the results suggested that the growth rates are not stationary.
[101] We employed the modified AIC criterion to select the number of lags in the Ng-Perron Test. For further details, see Ng and Perron (2001).

The results from the unit-root tests of the different variables considered in the rest of the work can be seen in the appendix. We conclude that all variables except the stock of physical and human capital are integrated of order one in levels. The stock of physical capital and human capital are integrated of order two with the majority of the tests considered; we therefore turn these variables into the first differences to look for long-run relationships among them and growth rates.

b) Cointegrating relationships

In order to carry out the cointegration analysis, we use the cointegrated VAR model proposed by Johansen (1988 and 1995), Johansen and Juselius (1990 and 1994) and Juselius (2007). One of the advantages of this methodology is its flexibility. It allows the interdependence of our variables to be tested by initially considering all relevant variables as endogenous, and then explicitly analysing the weak exogeneity of one or more of them. In addition, the possibility of combining long-run and short-run information in the data by exploiting the cointegration property together with the possibility of establishing casual economic relationships among the variables of interest are probably the most important reasons why the cointegrated VAR model continues to receive the interest of both econometricians and applied economists (Juselius, 2007).[102] We follow the most parsimonious approach of our initial model and then we reduce the model by imposing testable restrictions on the non-significant parameters in order to achieve economic interpretability (Hendry and Mizon, 1993; Juselius, 2007).

The unrestricted VAR model is given by:

$$\Delta Y_t = \alpha\beta_i^{'}\begin{pmatrix} Y \\ Z \\ t \\ D_s \end{pmatrix}_{t-1} + \sum_{i=1}^{k-1}\Gamma_i \Delta Y_{t-i} + \sum_{i=0}^{k-1}\omega_i \Delta Z_{t-i} + \sum_{i=0}^{k-1}\theta_i \Delta D_{st-i} + \varphi D_t + \mu + \varepsilon_t \qquad (2)$$

$$\varepsilon_t \sim NIID(0,\Sigma) \quad t = 1 \ldots T$$

[102] For example, it is possible to find other works that employ the cointegration techniques applied to the Chinese economy, like Chow (1987), Li (2000), Yao (2000) or Narayan et al. (2007), among others.

where Y_t is the matrix of endogenous variables since the beginning, α and β are matrices of dimension $p \times r$; α denotes the direction and speed of adjustment toward equilibrium and β' is the matrix of the cointegrated vectors. Z_t is the matrix of the weakly exogenous variables by assumption since the beginning, t is the linear trend restricted to the cointegration space,[103] and D_s is the matrix of the shift dummies restricted to the cointegration space to guarantee a reasonable degree of stability of our estimated parameters.[104] $\{\Gamma, \omega, \theta\}$ are the unrestricted parameters in the dynamics of the model, whereas φD_t denotes the two additional unrestricted permanent dummies and μ is a vector of unrestricted constants. Finally, we assumed that the error term ε_t is an i.i.d. Gaussian sequence $N(0, \Sigma)$ and the initial values, $Y_{-k+1}, \ldots Y_0$, are fixed.

Initially, given the large number of potentially endogenous variables, and following the specific-to-general approach used by Juselius and MacDonald (2000, 2004), we started the analysis with a five-dimensional system that alternatively included the GDP or labour productivity growth rate (Δ*lgdp or* Δ*lprod*), jointly with the rate of physical capital accumulation (Δ*lK*), R&D expenditure (*lrd*), openness – alternatively measured by the export-to-GDP ratio *(xgdp*), imports-to-GDP ratio (*mgdp*) or trade-to-GDP ratio (*tgdp*), and the real exchange rate (*lrer*). Once this model had been identified, we extended our empirical analysis by including the human capital accumulation (Δ*hc*). In all cases, and in order to capture the influence of the rest of the world on Chinese economic performance, we introduced the US GDP growth rate (*Δlgdpusa*) as an exogenous control variable.[105]

[103] The reason for including a trend in the cointegration space is that when the data show distinct tendencies we need to allow for linear trends in the cointegration relationships when testing for the cointegration rank.
[104] The shift dummy takes the form (0,0,1,1,1) and two shift dummies (1978 and 1994) were included in the GDP model and another two (1978 and 1984) were included in the labour productivity model. The permanent unrestricted dummy takes the form (0,0,1,0,0) and two (1976 and 1989) were included in all the models. It is possible to determine the break through the battery of stability tests. See Juselius (2007).
[105] The US GDP level seems to be non-stationary with the majority of the tests employed and its growth rate is stationary, but there are some tests that put that conclusion in doubt. Nevertheless, we use it as a control variable, thinking that it could have more influence in the short-run dynamics of the model than in the long run.

In addition, we also performed the weak exogeneity tests concluding that GDP growth and physical capital accumulation are the only endogenous variables in the GDP models, and the same happens when labour productivity is analysed, except when imports are used as a proxy of openness; in this case the endogenous variables were labour productivity growth and the real exchange rate.[106] To conclude the specification of our models, we found that two lags are enough to prevent autocorrelation problems and to capture the dynamic effects following the LM test.

Once we have a well-specified model, its possible to obtain the number of long-run relations *(r)*, and the common driving trends *(p-r)* with the likelihood ratio (LR) trace test, the roots of the companion matrix and the graphics of the long-run relations expressed as deviations from steady-state.[107] The procedure starts by examining the null hypothesis $r=0$ and if this is rejected, the next null hypothesis, $r=1$, is examined until it is not rejected. Thus, with all this information, we can conclude that everything seems to indicate that just one long-run relationship exists in all the models estimated in this paper. To achieve economic interpretability of these long-run relationships, over-identifying restrictions have been included in the non-significant coefficients that were accepted by the data.[108] Furthermore and in accordance with the battery of stability tests, the concentrated version of the model seems reasonably stable.

3.4 Empirical Results

a) Long-run Effects

Our results are presented in Tables 2 and 3. Table 2 is concerned with the long-run relationships between the variables considered in each model, that is, the cointegrating vectors,

---

[106] Weak exogeneity test and the stability tests were omitted in the paper to save space. These tests are available from the authors on request together with the residual analyses.

[107] In accordance with Johansen (1995), the vector process is based on asymptotic distributions that depend on the deterministic terms in the VAR model and this is why we have simulated the distribution of the rank test in CATS for RATS. In the appendix we only show the rank test and the root of companion matrix. The graphs of the long-run relations are available upon request, due to the large number of models that were estimated. The determination of the rank test was based on all this information. We have accepted one cointegrated vector for all models that were estimated, although some rank tests reject the null, given that if we allow $r = 2$, then the graph of the second cointegrated vector shows that it is clearly a non-stationary process.

[108] See Juselius (2007).

and Table 3 shows the short-run dynamics. In Table 2 all the long-run relationships are expressed as deviations from the steady state, normalized in GDP and labour productivity growth rates, respectively. Nevertheless, it is not possible to interpret the coefficients in the cointegrated VAR model as in the traditional econometric methods, given that a shock to one variable is transmitted to all variables via dynamics of the system until the system has found its new equilibrium position (Juselius, 2007). Moreover, it is possible to examine the direction of the causality in the Granger sense by analysing the significance of the coefficients in the cointegrating vectors and through the coefficient of the error correction mechanisms (*ecm*) in the dynamics.

Table 2. Cointegrating Long-Run Relationships

A) GDP Models

Initial Models		Δlgdp	Δlk	lrd	tgdp	xgdp	mgdp	lrer	Restrictions
Trade-to-GDP Model	ecm_1	1	-0.58 [-7.48]	-0.09 [-10.42]	-0.45 [-13.37]			0	$\chi^2(2)=2.513(0.285)$
Exports-to-GDP Model	ecm_2	1	-0.60 [-4.82]	-0.08 [-8.29]		-0.58 [-5.10]		-0.10 [-4.23]	$\chi^2(1)=2.396(0.122)$
Imports-to-GDP Model	ecm_3	1	-0.28 [-3.51]	-0.08 [-8.96]			-0.74 [-12.06]	0	$\chi^2(2)=1.120(0.571)$

Models with Human Capital		Δlgdp	Δlk	Δhc	lrd	tgdp	xgdp	mgdp	lrer	Restrictions
Trade-to-GDP Model	ecm_1	1	-0.52 [-5.69]	-0.17 [-7.62]	-0.09 [-11.04]	-0.34 [-6.14]			-0.23 [-6.27]	$\chi^2(2)=4.388(0.111)$
Exports-to-GDP Model	ecm_2	1	-0.66 [-5.22]	-0.25 [-8.23]	-0.08 [-7.56]		-0.51 [-4.33]		-0.36 [-9.51]	$\chi^2(2)=1.284(0.526)$
Imports-to-GDP Model	ecm_3	1	-0.38 [-5.68]	0	-0.07 [-10.02]			-0.71 [-13.80]	0	$\chi^2(3)=1.737(0.629)$

B) Labour Productivity Models

Initial Models		Δlprod	Δlk	lrd	tgdp	xgdp	mgdp	lrer	Restrictions
Trade-to-GDP Model	ecm_1	1	-0.77 [-9.55]	-0.07 [-9.76]	-0.62 [-14.19]			0.11 [5.70]	$\chi^2(2)=0.165(0.921)$
Exports-to-GDP Model	ecm_2	1	-0.86 [-8.44]	-0.08 [-8.41]		-0.95 [-11.40]		0	χ^2 (3)=1.79 (0.61)
Imports-to-GDP Model	ecm_3	1	-0.42 [-3.85]	-0.05 [-7.57]			-1.27 [-10.42]	0.18 [5.03]	$\chi^2(3)=0.825(0.844)$

Models with Human Capital		Δlprod	Δlk	Δhc	lrd	tgdp	xgdp	mgdp	lrer	Restrictions
Trade-to-GDP Model	ecm_1	1	-0.71 [-9.03]	-0.10 [-6.20]	-0.07 [-9.41]	-0.63 [-14.51]			0	$\chi^2(4)=7.856(0.097)$
Exports-to-GDP Model	ecm_2	1	-1.01 [-9.00]	-0.05 [-2.73]	-0.07 [-7.72]		-1.07 [-10.40]		0	$\chi^2(3)=4.911(0.178)$
Imports-to-GDP Model	ecm_3	1	-0.57 [-5.72]	0	-0.05 [-5.72]			-1.40 [-11.33]	0.24 [6.14]	$\chi^2(4)=1.946(0.746)$

Note: We show only the coefficients of the stochastic variables; the deterministic components are available upon request.
t-statistics in brackets

In Panel A, we report the estimates of GDP growth rate with and without human capital together with the three alternative measures of openness, that is, our initial model and the extended model with human capital. In all the cases the coefficients show the expected signs and are significant. Thus, Panel A in Table 2 describes how net investment, openness and R&D expenditure account for GDP growth rate in the long run. Furthermore, when human capital is included, we found that it is an additional factor in accounting for GDP growth, except when imports are included. The direction of the causality is unidirectional and runs from physical and human capital accumulation, openness, and R&D expenditure, to GDP growth rate. In Panel B in Table 2, we present the estimates of labour productivity growth rate in the same way as GDP growth, and the estimated coefficients are also significant and have the expected signs. We found that labour productivity responds to the fluctuation of net investment, openness and R&D activities and hence they have a positive long-run effect on labour productivity growth rate. Similar results were found regarding the effect of human capital on labour productivity compared with the previous model. Once again, the direction of the causality is unidirectional running from net investment, openness, R&D and human capital to labour productivity.

Thus, in agreement with the endogenous growth models, and as can be seen in Table 2, Panels A and B, the coefficient of physical capital growth rate is highly significant after identifying these long-run relationships, and the restrictions equal to zero in these coefficients are not accepted by the data. As is evident from (10), the AK-type models imply that the rates of growth and net investment move in the same direction in the long run. Similar conclusions may be found with regard to human capital. Our results suggest that human capital is highly significant when trade-to-GDP or exports-to-GDP are included in the model. However, when imports were examined, we found that human capital is not significant in these models. This effect is probably accounted for by the fact that the majority of imports consist in capital and intermediate goods coming from developed countries and their influence on growth rates is quite strong, thereby weakening the modest influence of human capital. Analogously, and in accordance with the predictions of the R&D-based growth models, a permanent increase in the level of resources devoted to R&D leads to a permanent increase in growth rates, as shown in Table 2. The innovation activities are significant regardless of the trade measure utilized.

In addition, and in line with the predictions of the new growth theory on the effect of openness on the rate of economic growth, we found that openness to international trade has played a significant role in economic growth in China. Moreover, this trade effect is robust to the openness measure that was utilized. In line with other studies, like Shan and Sun (1998), Liu et al. (1997 and 2002) or Siebert (2007) for example, we found that exports have contributed exogenously to stimulate long-run growth, which is consistent with the *export-led* hypothesis. Additionally, unlike other studies, we found new evidence that imports have also favoured economic growth during the period under consideration, thus following the *import-led* growth hypothesis. In this sense, our findings are more in agreement with the defenders of the positive effects that openness to trade has on growth than with those who argue that trade is more a consequence of growth than one of its causes. In our case, however, openness only has a positive role on growth when capital accumulation (in the broad sense of the term) and R&D are considered jointly.[109] This somehow reconciles the visions of the strictest defenders of the beneficial effect of openness on growth (Frankel and Romer, 1999; Baldwin, 2003, among others) with the one belonging to those somewhat more heterodox authors who have highlighted the influence of other domestic factors on the process of growth in developing economies (for example, Rodrik, 1995).

These findings, together with the permanent effects of R&D expenditure and physical and human capital on the growth rate of the Chinese economy are more consistent with some version of the endogenous growth models than with Solow's model of growth.

Finally, a singular regularity is found in all the models that were estimated that has to do with the real exchange rate. In all the cases in which it is significant, we found that depreciation has a positive effect on growth. This evidence is consistent with the hypothesis that the Renminbi has been employed as an additional instrument of economic development policy. Everything seems to indicate that maintaining a competitive exchange rate has been a suitable factor in Chinese growth over the period under consideration, and its influence has worked for channels other than through stimulating trade (Gala, 2008; Rodrik, 2008).

[109] Thus, our results are more in line with the works of Levine and Renelt (1992), Baldwin and Seghezza (1996) or Wacziarg (2001).

b) Short-Run Dynamics

Finally, the estimated dynamics of our models are presented in Table 3, Panels A and B, to complete the specification and to examine the stationary of our long-run relations. The procedure starts with the most parsimonious model, and the non-significant coefficients are then eliminated sequentially until the most irreducible form is reached. Furthermore, the coefficient of the error correction term (*ecm*$_i$) can be interpreted as the speed of adjustment towards equilibrium. This coefficient has to be negative and significant in the first difference equation of the variable in which the cointegrating vector has been normalized so that it can be interpreted in economic terms.

Table 3: Short-Run Dynamics

A) GDP Models

	Initial Models						Models with Human Capital					
	Trade		Exports		Imports		Trade		Exports		Imports	
Variables	Δ^2lgdp	Δ^2lk	Δ^2lgdp	Δ^2lk	Δ^2lgdp	Δ^2lk	Δ^2lgdp	Δ^2lk	Δ^2lgdp	Δ^2lk	Δ^2lgdp	Δ^2lk
Δ^2lgdp$_{t-1}$	0.43	-	0.38	-	0.37	-	0.59	0.11	0.23	-	0.30	-
	(8.52)		*(5.92)*		*(7.88)*		*(4.29)*	*(2.04)*	*(3.55)*		*(6.11)*	
Δ^2lk$_t$							-	-	-	-	-1.07	-0.72
											(-2.61)	*(-3.62)*
Δ^2lk$_{t-1}$	-	-0.34	-	-0.35	-	-0.53	-0.99	-0.43	-1.34	-0.44	-	-
		(-4.28)		*(-3.75)*		*(-5.92)*	*(-2.57)*	*(-2.51)*	*(-3.34)*	*(-2.78)*		
Δhc							-	0.10	-	0.09	-0.10	-
								(6.46)		*(5.06)*	(-3.17)	
Δhc$_{t-1}$							-	-	-	-	0.11	-
											(2.94)	
Δlrd	0.21	0.05	0.21	0.04	0.20	0.05	0.16	0.04	0.21	0.06	0.18	0.05
	(7.75)	*(3.55)*	*(7.04)*	*(3.32)*	*(7.66)*	*(3.99)*	*(4.64)*	*(2.65)*	*(6.28)*	*(4.93)*	*(6.17)*	*(3.71)*
Δlrd$_{t-1}$	0.07	-	0.06	-	0.07	-	0.05	-	0.04	-	0.08	-
	(4.89)		*(3.46)*		*(4.93)*		*(3.58)*		*(2.49)*		*(5.61)*	
Δtgdp$_{t-1}$	-	0.24					-	0.18				
		(4.44)						*(5.03)*				
Δxgdp$_{t-1}$			-0.51	-					-	-		
			(-3.74)									
Δmgdp$_{t-1}$					0.22	0.35					-	0.35
					(2.16)	*(5.67)*						*(5.60)*
Δlrer	0.10	-	0.08	-	-	-	0.55	-	0.28	-0.17	0.15	-
	(2.48)		*(1.81)*				*(11.7)*		*(2.04)*	*(-3.19)*	*(3.82)*	
Δlrer$_{t-1}$	0.13	-	-	-	-	-	0.10	-	-	-	0.13	-
	(2.64)						*(2.20)*				*(3.26)*	
Δ^2lgdpusa	0.21	-	-	-	0.26	-	0.49	-	-	-0.23	0.37	-
	(3.00)				*(3.76)*		*(6.61)*			*(-6.35)*	*(5.35)*	
Δ^2lgdpusa$_{t-1}$	0.35	-	0.23	-	0.33	-	0.28	-	0.28	-	0.29	-
	(5.91)		*(3.18)*		*(5.64)*		*(4.91)*		*(3.84)*		*(5.00)*	
ecm$_{1t-1}$	**-1.78**	**0.37**					**-1.29**	**0.25**				
	(-12.3)	*(4.89)*					*(-5.57)*	*(2.46)*				
ecm$_{2t-1}$			**-1.93**	**0.39**					**-1.18**	**0.68**		
			(-10.2)	*(4.58)*					*(-3.47)*	*(5.30)*		
ecm$_{3t-1}$					**-1.81**	**0.44**					**-1.88**	**0.83**
					(-12.3)	*(5.49)*					*(-4.83)*	*(4.64)*
Restrictions	$\chi^2(15)$=22.878 (0.0868)		$\chi^2(19)$=29.224 (0.0625)		$\chi^2(20)$=25.486 (0.1835)		$\chi^2(18)$=24.951 (0.1263)		$\chi^2(20)$=25.891 (0.1695)		$\chi^2(20)$=31.189 (0.0527)	

For all the cases, that is, in the Δ^2lgdp and Δ^2lprod equations, it can be seen that they are error-correcting with the respective long-run relationship found in each model. The speed of adjustment toward equilibrium is reasonably fast, hence indicating that these economic relations are stationary.

Table 3: Short-Run Dynamics (Cont.)
B) Labour Productivity Models

	Initial Models						Models with Human Capital					
	Trade		Exports		Imports		Trade		Exports		Imports	
Variables	Δ^2lprod	Δ^2lk	Δ^2lprod	Δ^2lk	Δ^2lprod	Δ^2lrd	Δ^2lprod	Δ^2lk	Δ^2lprod	Δ^2lk	Δ^2lprod	Δ^2lrer
Δ^2lprod$_{t-1}$	0.45	-	0.36	-	0.46	0.97	0.32	-	0.47	-	0.32	-
	(7.36)		*(5.05)*		*(5.08)*	*(1.80)*	*(6.82)*		*(7.10)*		*(5.09)*	
Δ^2lk$_t$							-	-	-	-	1.52	-
											(10.2)	
Δ^2lk$_{t-1}$	-	-0.23	-	-0.25	1.58	3.75	-	-	-	-0.28	-	0.77
		(-3.11)		*(-3.24)*	*(6.60)*	*(2.39)*				*(-3.56)*		*(1.93)*
Δhc							-	0.04	0.13	-	-0.11	-
								(2.37)	(3.02)		*(-2.80)*	
Δhc$_{t-1}$							-	-	-	-	0.14	-0.29
											(2.96)	*(-2.15)*
Δlrd	0.20	0.04	0.24	0.05	-	-	0.22	0.06	0.24	0.05	0.10	-
	(6.90)	*(3.09)*	*(7.12)*	*(3.69)*			*(8.07)*	*(3.66)*	*(8.06)*	*(3.38)*	*(6.71)*	
Δlrd$_{t-1}$	0.08	-	-	-0.03	0.09	-	0.08	-	0.05	-	0.10	-
	(4.79)			*(-3.59)*	*(4.97)*		*(5.94)*		*(3.62)*		*(6.30)*	
Δtgdp	0.36	-					0.31	-		-		
	(6.27)						*(4.91)*					
Δtgdp$_{t-1}$	-0.49	-					-0.49	-		-		
	(-5.29)						*(-6.11)*					
Δxgdp$_t$			-	-0.30					0.85	-		
				(-5.47)					*(8.12)*			
Δxgdp$_{t-1}$			-	0.27					-	0.36		
				(4.26)						*(5.64)*		
Δmgdp$_t$					0.67	-				-	0.91	1.32
					(5.08)						*(8.29)*	*(3.26)*
Δmgdp$_{t-1}$					-0.78	-				-	-1.02	-
					(-4.38)						(-7.47)	
Δlrer	0.18	-	-	-	-	-	-	-0.10	-	-	-	-
	(3.37)							*(-3.82)*				
Δlrer$_{t-1}$	-	-	-	-	0.20	-	0.14	-	-	-	0.29	-
					(3.68)		*(2.91)*				*(6.74)*	
Δ^2lgdpusa	0.38	-	-	-0.08	0.47	-	-	-0.27	0.22	-	0.60	-
	(4.82)			*(-2.20)*	*(5.19)*			*(-6.50)*	*(2.82)*		*(7.62)*	
Δ^2lgdpusa$_{t-1}$	0.47	-	0.33	-	0.49	-	0.38	-	0.36	-	0.47	-
	(7.07)		*(4.12)*		*(6.04)*		*(7.00)*		*(5.28)*		*(6.66)*	
ecm$_{1t-1}$	**-2.37**	**0.39**					**-1.96**	**0.29**				
	(-11.3)	*(4.05)*					*(-11.8)*	*(3.30)*				
ecm$_{2t-1}$			**-2.54**	**0.88**					**-2.19**	**0.50**		
			(-7.63)	*(5.78)*					*(-10.4)*	*(5.04)*		
ecm$_{3t-1}$					**-2.55**	**-1.70**					**-2.95**	**-0.70**
					(-17.4)	*(2.77)*					*(-20.3)*	*(-2.79)*
Restrictions	$\chi^2(20)=26.713$ (0.1435)		$\chi^2(21)=27.365$ (0.1591)		$\chi^2(22)=19.834$ (0.5934)		$\chi^2(19)=29.310$ (0.0613)		$\chi^2(23)=28.262$ (0.2060)		$\chi^2(21)=29.070$ (0.1123)	

A feature that is common to the various specifications (Panel A and B) is that the main effect of the accumulation of physical and human capital, as well as that of the majority of the indicators of openness, is produced through long-run relationships, with little if any impact on the short-run dynamics. This result reinforces the relevance of these factors as determinants of long-run growth.

With regard to the other variables that were considered, note the positive influence in the short run of increased spending on R&D, both on variations in growth rates of GDP and productivity, and on variations in investment. Similarly, improvements in competitiveness stimulate the growth rate of output and, to a lesser extent, productivity in the short run;

something similar happens with the changes in the US growth rate, thus reflecting some cyclical foreign impact. Finally, it is noteworthy that increases in the imports-to-GDP ratio raise both the growth rate of the GDP and the rate capital accumulation.

3.5 Conclusions

The main objective of this paper has been to unravel the relevance of endogenous growth models in explaining the Chinese economic growth from 1965 to 2000, more for the policy and economic implications of this type of models than with the aim of testing its empirical relevance explicitly. Specifically, we have explored the time series properties of the growth rates of GDP and labour productivity, and the role played in their short- and long-run determination by both physical and human capital accumulation and their interactions with other sources of economic growth like openness to trade, R&D expenditure, and competitiveness. Additionally, to provide evidence of the robustness of our results, we considered three alternative measures of trade (exports, imports and overall trade to GDP).

Our findings suggest that both the growth rate of GDP and the growth rate of labour productivity are non-stationary, that is, they exhibit large persistent movements. Additionally, capital accumulation (understood in a broad sense namely, including physical and human capital) is among the most important driving forces behind China's growth. Furthermore, in accordance with different extensions of endogenous growth models, we found that the level of the resources involved in the R&D activities and openness (independently of the measure used: trade, exports or imports to GDP) guide and positively affect output and labour productivity growth rates in the long run. Finally, we found evidence that maintaining a competitive real exchange rate has also played a significant role in the explanation of the long-run rate of growth of output and labour productivity in the period that was analysed. These findings, considered jointly, allow us to state that the growth process experienced by the Chinese economy has not only been the result of a process of factor accumulation, but at least this factor accumulation has co-existed with significant efficiency gains in the long run. Thus, although it is difficult to discriminate strictly among different models of growth, our results seem more consistent with the implications of certain versions of the endogenous growth models than with the Solow-type models of growth.

However, although from the perspective of increasing their rate of economic growth, the economic development strategy pursued by the Chinese authorities has been worthwhile, there are deep structural problems that may be a source of increasing constraints in the future and we have to qualify our findings. First of all, the remarkable process of growth has to be translated into improvements in the income distribution and in the economic welfare of the population. These objectives are incompatible with the current strategy of enhancing the costal and urban areas at the expense of rural ones (increasing interregional income inequality) and with the policy option of stressing the weight of investment at the expense of consumption in the composition of the GDP.

Second, although physical capital was found to be a source of long-run growth in China, the sustainability of the high rates of saving and investment to GDP is dubious, not only because this strategy has significant costs in terms of low levels of consumption, but because in the future it could affect the productivity of capital and the efficiency of investment. Thus, despite its positive effect on growth rate, it does not seem feasible to carry out further increases in saving and investment rates and in the future they may even descend. Consequently, this scenario will affect the pace at which technological innovation is incorporated into the stock of installed capital and can weaken the forces that offset the tendency towards diminishing returns in the accumulation of capital. Nevertheless, from our point of view some possible options to offset this tendency do exist. It is well known that there are significant inequalities across provinces in China, and if we look at the regional variation in the structure of capital we can observe that it is fundamentally located in the coastal provinces. Thus, in principle, one possibility allowing the aforementioned investment policy to continue is to redistribute new investment across the less developed provinces in China. However, this possibility is not free of risks and difficulties, above all because it would be necessary to invert some of the tendencies that have resulted from the combination of interventionist policies together with a major market-oriented economy.

From another point of view, given that we have found that human capital and innovation activities exert a positive and direct influence on economic growth, and that these two key factors are relatively scarce in the Chinese economy, both in absolute terms and when they are compared with developed countries, there is still considerable scope to stimulate technological innovation and human capital accumulation, while at the same time making growth more balanced and sustainable.

Finally, the various reforms implemented to facilitate the integration of China into the international markets have made it one of the largest traders in the world, and everything seems to indicate that this strategy has also given good results. However, high investment rates have intensified its dependence on imported capital and intermediate goods, thus weakening internal demand and increasing foreign dependence. This, in turn, has increased the need for high levels of exports in order to prevent foreign constraint. Until now this need for elevated exports does not seem to have been a problem, but there are some critics who believe that maintaining the current rates of exports to GDP is not sustainable because it depends on the ability of the foreign demand to absorb the Chinese products and makes the economy more exposed to external shocks.

This last warning might also be affected by the sustainability of exchange rate policy. Thus, although until now maintaining a competitive exchange rate seems to have served as a stimulus to growth, it seems difficult to systematically keep it up because of the imbalances that this strategy entails in terms of reserve accumulation and its implications for monetary policy management.

To conclude, although our results suggest that there are signs of a successful growth progress in the Chinese economy in the past, with significant gains in efficiency, deep structural problems still subsist and their own growth process has involved significant distortions, thus making it necessary to introduce more economic reforms in order to guarantee the sustainability of economic growth and development in the future.

Appendix 3A

Unit Root Tests

Table 3A.1 Unit Root Tests

	ADF			PP			KPSS	
	Null: Unit Root			Null: Unit Root			Null: Stationary	
	none	const.	trend	none	const.	trend	const.	trend
xgdp	3.42	1.32	-1.07	2.90	1.55	-1.39	0.78*	0.21**
Δxgdp	-1.44	-6.25*	-5.97 *	-5.61*	-6.23*	-6.92*	0.43*	0.04
mgdp	2.54	1.14	-2.26	2.29	0.92	-1.80	0.80*	0.12***
Δmgdp	-3.89*	-4.33*	-4.63*	-3.93*	-4.37*	-4.54*	0.39***	0.06
tgdp	-1.07	1.69	-1.07	3.15	1.69	-1.07	0.80*	0.17**
Δtgdp	-4.43*	-5.04*	-5.57*	-4.47*	-5.05*	-5.57*	0.42***	0.06
lrd	3.33	0.79	-1.47	5.25	-0.19	-2.39	0.81*	0.13***
Δlrd	-4.85 *	-5.60 *	-5.64 *	-4.81*	-6.88*	-6.64*	0.12	0.06
lrer	2.09	-1.01	-1.46	1.95	-1.01	-1.63	0.78*	0.10*
Δlrer	-4.99*	-5.66*	-5.64*	-4.99*	-5.61*	-5.58*	0.12	0.10
lk	4.56	2.92	-0.72	20.88	3.82	-2.96	0.75*	0.19**
Δlk	0.18	-2.67 ***	-3.87**	-0.27	-4.01*	-4.01**	0.66**	0.13*
hc	1.59	-0.71	-1.41	3.64	-0.43	-1.48	0.80*	0.14*
Δhc	-0.62	-1.60	-1.62	-0.93	-2.19	-2.17	0.13	0.12*
lgdpusa	4.00	-0.97	-4.93*	10.50*	-1.76	-4.13**	0.83*	0.09
Δlgdpusa	-1.25	-4.99*	-5.01*	-2.08**	-4.99*	-5.08*	0.24	0.12*

	Ng-Perron						LLS Test	
	Null: Unit Root						Null: Unit Root	
	Constant			Trend				
	MZ_α	MZ_t	MSB	MZ_α	MZ_t	MSB	None	trend
xgdp	3.17	1.84	0.58	-4.87	-1.16	0.23	-0.81	-1.81
Δxgdp	-20.93*	-3.09*	0.14*	-20.73**	-3.15**	0.15**	-3.72 *	-3.14 *
mgdp	1.91	0.81	0.42	-6.02	-1.35	0.22	1.79	-1.89
Δmgdp	-18.48*	-2.85*	0.15*	-19.35**	-3.04**	0.15**	-3.84 **	-3.00**
tgdp	2.98	1.58	0.52	-3.90	-0.95	0.24	-0.86	-2.27
Δtgdp	-20.28*	-2.99*	0.14*	-14.20 *	-2.57 **	0.18 *	-3.28 *	-3.30 *
lrd	1.38	0.78	0.56	-8.60	-1.98	0.23	-0.21	-2.61
Δlrd	-12.19 **	-2.42 **	0.19 **	-23.66**	-3.43 **	0.14 **	-5.77*	-4.46 *
lrer	0.73	0.74	1.01	-5.32	-1.53	0.28	-1.12	-1.96
Δlrer	-9.15 **	-2.13 **	0.23 **	-20.53**	-3.19**	0.15**	-3.88 *	-3.76 *
lk	1.85	1.96	1.06	-3.08	-1.06	0.34	1.52	-0.70
Δlk	-0.04	-0.04	1.03	-0.94	-0.49	0.52	-3.37 **	-1.50
hc	-8.16 ***	-1.83 ***	0.22 ***	-10.46	-2.26	0.21	-1.94	-2.39
Δhc	-10.09 **	-2.23 *	0.22 **	-10.30	-2.26	0.21	-1.70	-2.00
lgdpusa	0.76	0.48	0.63	-7.45	-1.90	0.25	0.51	-1.93
Δlgdpusa	-0.58	-0.53	0.91	-19.56**	-3.10**	0.15**	-5.03 *	-4.67 *

Note: The tests were performed with Eviews and JMULTI. * Rejection of the null at 10%; ** Rejection of the null at 5%; and *** Rejection of the null at 1%.

Appendix 3B

Determination of the Rank and Roots of Companion Matrix[110]

Table 3B.1 GDP Model with Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.76	75.00	71.68	45.68	0.000	0.000
1	1	0.47	22.88	22.61	23.70	**0.064**	**0.068**

Note: In all tables (*) corresponds to the trace test with Bartlett's correction. The asymptotic distributions have been simulated for the current deterministic specifications in all models using CATS for RATS.

	H(0)	H(1)	H(2)
Root1	1	1	0.76
Root2	1	**0.74**	0.76
Root3	0.58	0.74	0.70
Root4	0.58	0.49	0.67

Table 3B.2 GDP Model with Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.64	56.51	53.93	46.25	0.004	0.008
1	1	0.42	19.63	19.47	23.43	**0.142**	**0.148**

	H(0)	H(1)	H(2)
Root1	1	1	0.77
Root2	1	**0.68**	0.66
Root3	0.53	0.68	0.66
Root4	0.53	0.20	0.41

Table 3B.3 GDP Model with Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.85	96.82	92.52	45.86	0.000	0.000
1	1	0.53	27.79	27.30	23.48	0.015	0.018

	H(0)	H(1)	H(2)
Root1	1	1	0.74
Root2	1	**0.69**	0.66
Root3	0.53	0.69	0.66
Root4	0.53	0.31	0.57

Table 3B.4 GDP Model with Human Capital and Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.893	109.416	105.039	50.627	0.000	0.000
1	1	0.552	28.876	28.153	26.247	0.023	0.028

	H(0)	H(1)	H(2)
Root1	1	1	0.70
Root2	1	**0.66**	0.70
Root3	0.61	0.66	0.60
Root4	0.61	0.20	0.20

[110] We have accepted one cointegrated vector for all models estimated, although some rank tests reject the null, given that if we allow r = 2, this second long-run relationship is not stationary. In addition, in order to select the rank of the long-run matrix, it is possible to check additional information such as the graphics of cointegrated vectors, which clearly show that one stationary relationship in this VAR model exists, while the others are not stationary.

Table 3B.5 GDP Model with Human Capital and Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.795	81.932	78.660	50.432	0.000	0.000
1	1	0.498	24.814	24.203	26.855	**0.074**	**0.087**

	H(0)	H(1)	H(2)
Root1	1	1	0.73
Root2	1	**0.70**	0.73
Root3	0.61	0.70	0.63
Root4	0.61	0.03	0.01

Table 3B.6 GDP Model with Human Capital and Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.899	117.567	112.963	50.163	0.000	0.000
1	1	0.621	34.940	34.069	25.681	0.003	0.004

	H(0)	H(1)	H(2)
Root1	1	1	0.68
Root2	1	**0.64**	0.66
Root3	0.62	0.64	0.66
Root4	0.62	0.32	0.43

Table 3B.7 Labour Productivity Model with Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.92	122.66	117.54	56.50	0.000	0.000
1	1	0.53	27.88	27.19	28.74	**0.066**	**0.078**

	H(0)	H(1)	H(2)
Root1	1	1	0.71
Root2	1	**0.69**	0.71
Root3	0.57	0.69	0.68
Root4	0.57	0.51	0.76

Table 3B.8 Labour Productivity Model with Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.89	105.41	101.02	54.47	0.000	0.000
1	1	0.49	24.21	23.84	27.80	**0.135**	**0.147**

	H(0)	H(1)	H(2)
Root1	1	1	0.70
Root2	1	**0.68**	0.70
Root3	0.57	0.68	0.68
Root4	0.57	0.57	0.63

Table 3B.9 Labour Productivity Model with Imports-to- GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.90	123.30	111.85	45.73	0.000	0.000
1	1	0.64	37.53	35.48	23.51	**0.000**	**0.001**

	H(0)	H(1)	H(2)
Root1	1	1	0.84
Root2	1	**0.68**	0.84
Root3	0.21	0.68	0.46
Root4	0.03	0.01	0.11

Table 3B.10 Labour Productivity Model with Human Capital and Trade-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.83	94.22	90.03	50.86	0.000	0.000
1	1	0.55	29.16	28.41	26.13	0.021	0.026

	H(0)	H(1)	H(2)
Root1	1	1	0.62
Root2	1	**0.49**	0.56
Root3	0.55	0.49	0.56
Root4	0.55	0.32	0.29

Table 3B.11 Labour Productivity Model with Human Capital and Exports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.89	117.60	112.99	60.38	0.000	0.000
1	1	0.64	36.80	35.88	31.12	0.011	0.015

	H(0)	H(1)	H(2)
Root1	1	1	0.75
Root2	1	**0.74**	0.71
Root3	0.63	0.74	0.71
Root4	0.63	0.13	0.34

Table 3B.12 Labour Productivity Model with Human Capital and Imports-to-GDP

p-r	r	Eig.Value	Trace	Trace*	95%	p-value	p-value*
2	0	0.90	95.43	87.99	50.21	0.000	0.000
1	1	0.22	9.17	8.70	26.11	**0.915**	**0.933**

	H(0)	H(1)	H(2)
Root1	1	1	0.86
Root2	1	**0.59**	0.61
Root3	0.13	0.59	0.61
Root4	0.01	0.05	0.14

References

Acemoglu, D., Johnson, S., Robinson, J.A., and Thaicharoen, Y. (2003). 'Institutional Causes, Macroeconomic Systems: Volatility, Crisis and Growth', *Journal of monetary Economics* 50. pp. 49-123.

Aghion, P. and Howitt, P. (1992). 'A model of Growth through creative destruction', *Econometrica* 60, pp. 323-351

Aghion, P. and Howitt, P. (1998). Endogenous Growth Theory. MIT Press, Cambridge, MA.

Bai, C., Hsieh, C. and Qian, Y. (2006). 'The Return to Capital in China', NBER Working papers No 12755

Baldwin, R. and Seghezza, E. (1996). 'Trade-induced investment-led growth', NBER Working papers No 5582.

Baldwin, R. E. (2003). 'Openness and Growth: What's the empirical relationship?' NBER Working papers No 9578

Barro, R. (2001). 'Human Capital and Growth' *The American Economic Review* 91, pp. 12-17

Benhabib, J. and Spiegel, (2005). Human Capital and Technology Diffusion. Handbook of Economic Growth. Philippe Aghion and Steven Durlauf (ed), edition1, volume 1, Chapter 13, 935-966 Elsevier.

Bernanke, B. and Gurkaynak, R. (2001). 'Is growth exogenous? Taking Mankiw, Romer, and Weil seriously'. NBER Working papers No 8365

Bils, M. and Klenow, P. (2000). 'Does schooling cause growth?', *The American Economic Review* 90, pp.1160-1183

Blomstrom, M., Lipsey, R. E., and Zejan, M., (1996). 'Is fixed investment the key to economic growth?', *The Quarterly Journal of Economics* 111, pp. 269-276

Bond, S., Leblebicioglu, A., and Schiantarelli, F. (2004). 'Capital Accumulation and Growth: A New Look at the Empirical Evidence', Economics Department. Boston College Working Paper, 591.

Borensztein, E., De Gregorio, J. and Lee, J-W. (1998). 'How does foreign direct investment affect economic growth?', *Journal of International Economics* 45, pp. 115-135.

Broda, C. and Weinstein, D. (2004). 'Globalization and the gains from variety'. NBER Working papers No 10314

Chen, J. and Fleisher, B. (1996). 'Regional Income Inequality and Economic Growth in China', *Journal of Comparative Economics* 22, pp. 141-164

Chen, Y. (2003). 'A non-radial Malmquist productivity index with an illustrative application to Chinese major industries', *International journal of production economics* 83, pp. 27-35.

Chi, W. (2008). 'The role of human capital in China's economic development. Review and new evidence', *China Economic Review*. doi:10.1016/j.chieco.2007.12.001

Chow, G. (1987). 'Money and price determination in China', *Journal of Comparative Economics* 11, pp. 319-333.

Chow, G. (1993). 'Capital Formation and Economic Growth in China', *The Quarterly Journal of Economics* 108, pp. 809-842

Chow, G. (2006). 'Are Chinese Statistics Reliable?', *Cesifo Economic Studies* 52, pp 396-414

Chow, G. (2008). 'Another look at the rate of increase in TFP in China', *Journal of Chinese Economic and Business Studies* 6, pp. 219-224

Chow, G. and Lin, A. (2002). 'Accounting for economic growth in Taiwan and mainland China: a comparative analysis', *Journal of Comparative Economics* 30, pp. 507-530.

Chuang, Y. (1998). 'Learning by doing, the Technology gap, and growth', *International Economic Review* 39, pp. 697-721

Clerides, S., Lach, S., and Tybout, J. (1998). 'Is learning by exporting important? Micro-dynamic Evidence from Colombia, Mexico, and Morocco', *Quarterly Journal of Economics* 113, pp. 903-47.

Coe, D T. and Helpman, E. (1995). 'International R&D spillovers', *European Economic Review* 39 pp. 859-887

Easterly, W. (2005). National Policies and Economic Growth: A Reappraisal. In P. Aghion and S. Durlauf (eds.) *Handbook of Economic Growth*, chap. 15. Elsevier.

Eaton, J. and Kortum, S. (2001). 'Trade in capital goods', *European Economic Review* 45, pp. 1195-1235.

Esfahani, H.S. (1991). 'Exports, Imports, and Economic Growth in Semi-Industrialized Countries', *Journal of Development Economics* 35, pp. 93-116.

Frankel, J. A. and Romer, D. (1999). 'Does Trade Cause Growth?', *The American Economic Review* 89, pp. 379-394

Fu, X. (2005). 'Exports, technical progress and productivity growth in a transition economy: a non-parametric approach for China', *Applied Economics* 37, pp. 725-739.

Gala, P. (2008). 'Real Exchange Rate Levels and Economic Development: Theoretical Analysis and Empirical Evidence', *Cambridge Journal of Economics* 32, pp. 273-288

Greenaway, D. and Kneller, R. (2007). 'Firm Heterogeneity, Exporting and Foreign Direct Investment', *Economic Journal* 117, pp. F134-F161

Grossman, G.M. and Helpman, E. (1991). Innovation and Growth in the Global Economy Cambridge, Massachusetts, MIT Press.

Helpman, E. and Krugman, P.R. (1985). Market Structure and Foreign Trade. The MIT Press.

Hendry, D.F. and Mizon, G.E. (1993). Evaluating econometric models by encompassing the VAR. In PC.B. Philips (ed).Models, methods and application of econometrics: Essays in Honor of A.R. Bergstron. MIT Press: Cambridge Mass.

Holz, C.A. (2005). OECD – China Governance Project: The Institutional Arrangements for the Production of Statistics", OECD Statistics Working Papers, 2005/1, OECD Publishing.

Howitt, P. and Aghion, P. (1998). 'Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth', *Journal of Economic Growth* 3, pp. 111-130

Hsiao, .S.T. and Hsiao, W. (2006). 'FDI, exports, and GDP in East and Southeast Asia—Panel data versus time-series causality analyses' *Journal of Asian Economics* 17,pp. 1082-1106

Jin, J.C. (2004). 'On the relationship between openness and growth in China: Evidence from provincial time series data' *The World Economy* 27, pp. 1571-1582

Johansen, S. (1988). 'Statistical Analysis of Cointegration Vectors', *Journal of Economic Dynamics and Control*, 12, pp. 231-254

Johansen, S. and Juselius, K. (1990). 'Maximum Likelihood Estimation and inference on cointegration-with Applications to the Demand for money' *Oxford Bulletin of Economics and Statistics* 52, pp. 169-210.

Johansen, S.and Juselius, K. (1994). 'Identification of the Long-run and the Short-run structure. An application to the ISLM model' *Journal of Econometrics* 63, pp. 7-36

Johansen, S. (1995). Likelihood-Based inference in cointegrated vector auto-regressive models. Advance Texts in Econometrics. Oxford University Press

Jones, C. I. (1995). 'Time Series Tests of Endogenous Growth Models' *Quarterly Journal of Economics* 110, pp. 495-525

Juselius, K. (2007). The cointegrated VAR model: Econometric methodology and macroeconomics applications. Oxford University Press

Juselius, K. and MacDonald, R. (2004). 'International parity relationships between the USA and Japan' *Japan and The World Economy* 16, pp. 17-34.

Juselius, K. and MacDonald, R. (2000). International parity relationships between Germany and the United States: A joint Modelling approach. Working paper. Institute of Economics. University of Copenhagen.

Kwiatkowski, D.; Phillips, P.C.B; Schmidt, P.; y Shin, Y. (1992). Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit-root', *Journal of Econometrics* 54, pp. 159-178.

Kocherlakota, N.R. and Yi, K-M. (1997). 'Is There Endogenous Long-Run Growth? Evidence from the United States and United Kingdom' *Journal of Money, Credit and Banking* 29, pp. 235-262.

Krugman, P. (1994). 'The myth of Asia's miracle', *Foreign Affairs* 73, pp. 62-78

Kwan, C.C.A., Wu, Y. and Zhang, J. (1999). 'Fixed Investment and Economic Growth in China' *Economics of planning* 32, pp. 67-79.

Lau, S.-H. P. (1999). 'I(0) In, integration and cointegration out: Time series properties of endogenous growth models', *Journal of Econometrics* 93, pp. 1-24.

Lau, S.-H. P. and Sin, C.-Y. (1997). 'Observational equivalence and a stochastic cointegration test of the neoclassical and Romer's increasing returns models', *Economic Modelling* 14, pp. 39-60.

Lanne, M., and Lütkepohl, H., (2002). 'Unit root tests for time series with level shifts: a comparison of different proposals' *Economic Letters* 75, pp. 109-114

Lanne, M., Lütkepohl, H., Saikkonen, P. (2002). 'Comparison of unit root tests for time series with level shifts', *Journal of Time Series Analysis* 23, pp. 667-685

Lee, J.W. (1995). 'Capital goods imports and long-run growth', *Journal of Development Economics* 48, pp. 91-110.

Levine, R. and Renelt, D. (1992). 'A sensitivity analysis of cross-country growth regressions' *The American Economic Review* 82, pp. 942-963.

Li, X. (2000). 'The Great Leap Forward, Economic Reforms, and the Unit Root Hypothesis: Testing for Breaking Trend Functions in China's GDP Data', *Journal of Comparative Economics* 28, pp. 814–827.

Li, D. (2002). 'Is the AK model still alive? The long-run relation between growth and investment re-examined', *Canadian Journal of Economics* 35, pp. 92-114

Lin G. and Schramm R. (2003). 'China's foreign exchange policies since 1979: A review of developments and an assessment', *China Economic Review* 14, pp. 246-280

Liu, X., Song, H. and Romilly P. (1997). 'An empirical investigation of the causal relationship between openness and economic growth in China', *Applied Economics* 29, pp. 1679-86

Liu, X. Burridge P. and Sinclair P.J.N. (2002). 'Relationships between economic growth, foreign direct investment and trade: evidence from China' *Applied Economics* 34, pp. 1433-1440.

Lucas, R. E. JR. (1988). 'On the Mechanics of Economic Development' *Journal of Monetary Economics*, 22, pp. 3-42.

Mazumdar, J. (2001). 'Imported machinery and growth in LDCs', *Journal of Development Economics* 65, pp. 209-224.

Melitz, M.J. (2003). 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica* 71, pp. 1695-1725

Mody, A. and Yilmaz, K. (2002). 'Imported Machinery for Export Competitiveness', *World Bank Economic Review*, Oxford University Press 16, pp. 23-48

Narayan, P.K., Nielsen, I. and Smyth, R. (2007). 'Panel data, cointegration, causality and Wagner's law: Empirical evidence from Chinese provinces' *China Economic Review*, doi:10.1016/j.chieco.2006.11.004

Ng, S., and Perron, P. (2001). 'Lag length selection and the construction of unit root test with good size and power', *Econometrica* 69, pp. 1519-1554

Perron, P. and Ng, S. (1996). 'Useful Modifications to Unit Root Tests with Dependent Errors and their Local Asymptotic Properties', *Review of Economic Studies* 63, pp. 435–465.

Qin, D., Cagas, A., Quising, P. and He, X. (2005). 'How much Does Investment Drive Economic Growth in China?', Queen Mary University of London, Department of economics, working paper No 545.

Rebelo, S. (1991). 'Long-Run Policy Analysis and Long-Run Growth', *Journal of Political Economy* 99, pp. 500-521.

Riezman, R.G., Summers, P.M. and Whiteman, C.H. (1996). 'The engine of Growth or its handmaiden? A time series assessment of export-led growth' *Empirical Economics*. 21, pp. 77-113.

Rodriguez, F. and Rodrik, D. (2001). 'Trade policy and economic growth: A sceptic's guide to the cross-national evidence' in B.S. Bernake and K. Rogoff (eds.) *NBER Macroeconomics Annual 2000*, The MIT press Cambridge.

Rodrik, D. (1995). 'Getting interventions right how South Korea and Taiwan grew rich', *Economic Policy* 10, pp. 53-107

Rodrik, D. (1999). 'New Global Economics and Developing Countries: Making the Openness Work' Policy Essay No. 24. Washington D.C. Overseas Development Council. Johns Hopkins University Press, Baltimore.

Rodrik, D. (2008). 'The Real Exchange Rate and Economic Growth', Brookings Papers on Economic Activity. Forthcoming.

Romer, P. (1986). 'Increasing Returns and Long-Run Growth', *The Journal of Economics Perspectives* 8, pp. 3-22

Romer, P. (1990). 'Endogenous Technological Change', *Journal of Political Economy*, 98, pp. 71-103.

Saikkonen, P., and Lütkepohl H. (2002). 'Testing for a unit root in a time series with a level shift at unknown time', *Econometric Theory* 18, pp. 313-348

Shan, J. and Sun, F. (1998). 'On the export-led growth hypothesis: the econometric evidence from China', *Applied Economics* 30, pp. 1055-1065

Sianesi, B. and Reenen, J.V. (2003). 'The returns to education: Macroeconomics', *Journal of Economic Surveys* 17, pp. 157-200.

Siebert, H. (2007). 'China: Coming to Grips with the new global player', *The World Economy* 30, pp. 893 – 922

Wacziarg, R. (2001). 'Measuring the Dynamic Gains From Trade', *World Bank Economic Review* 15, pp. 393-429

Wang, Y. and Yao, Y. (2003). 'Sources of China's economic growth 1952-1999: incorporating human capital accumulation' *China Economic Review* 14, pp. 32-52.

Woo, W. T. (1998). 'Chinese Economic Growth: Sources and Prospects' In Michel Fouquin and Francoise Lemoine (ed.), *The Chinese Economy, Economica*, London, pp. 276-308.

Wu, Y. (2000). 'Is China's economic growth sustainable? A productivity analysis' *China Economic Review* 11, pp. 278-296.

Wu Y. (2004). China's Economic Growth. A miracle with Chinese characteristics. London and New York: Routledge Curzon Press.

Wu, Y. (2008). 'The role of productivity in China's Growth: New estimates', *Journal of Chinese Economic and Business Studies* 6, pp. 141-156.

Yao, S. (2000). 'How important is agriculture in China's economic growth?', *Oxford Development Studies* 28, pp. 33-50.

Yao, S. (2006), On economic growth, FDI and exports in China. *Applied Economics* 38, pp. 339-351

Young, A. (1995). 'The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience', *The Quarterly Journal of Economics* 110, pp. 641-680

Yu, Q. (1998). 'Capital investment, international trade and economic growth in China: Evidence in the 1980-90s', *China Economic Review* 9, pp. 73-84.

Zhang, Z. (2001). 'Real exchange rate misalignment in China: an empirical investigation' *Journal of Comparative Economics* 29, pp. 80-94.

Zheng, J., Wang, Z., Shi, J., (2008). 'Industrial productivity performance in Chinese regions (1987-2002): a decomposition approach', *Journal of Chinese Economic and Business Studies* 6, pp. 157-176.

Chapter IV

Weighted Convergence and Regional Clusters across China

4.1 Introduction

Income disparity across Chinese regions is a major concern among policymakers and also an interesting case of study from an academic point of view. Growing inequality increases redistributive tax pressure, which deters investment incentives and can also lead to a more unstable socio-political environment for economic activities (Alesina and Perotti, 1993; Alesina and Rodrik, 1994). Given its potential to thwart both economic growth and stabilisation, inequality and poverty reduction across regions is one of the fundamental problems that the Chinese government must solve and, accordingly, several initiatives have been undertaken to promote income distribution across Chinese regions. One of the most prominent ones took place in the early 2000s, when the Chinese government launched the Great Western Development Program (GWDP) with the aim of investing more in the western regions, where economic development is lower. The purpose of this programme was to balance the degree of development across regions and to reduce poverty, but this expectation has not been fulfilled as of today. Therefore, examining whether convergence is taking place across Chinese provinces is not only of great significance because of the sheer number of people whose welfare is involved

(China represents about one-fifth of the world's population), but also because it makes it possible to evaluate the success of policies designed to alleviate the magnitude of the inequalities. In addition to this, China has an economy that is undergoing a transition from a centrally planned to a more market-oriented economy and which has its own particular characteristics. Therefore, as indicated by Sakamoto and Islam (2008), the Chinese case could help to assess whether switching from central planning to a market mechanism makes a difference with regard to convergence. This could be increased further to examine whether interregional differences in income levels tend to disappear or to increase over time as a result of this transformation.

As indicated by Islam (2003), there are different definitions of convergence, each of which is linked to growth theory in a different way. According to this author, not only are there different ways in which convergence can be understood but also different methodologies to evaluate it. The definitions would include convergence *within* an economy versus *across* economies, growth *rates* versus income *level* convergence, β-convergence versus σ-convergence, *unconditional* versus *conditional* convergence, *global* versus *local* or *club*-convergence, and *deterministic* versus *stochastic* convergence. The methods would be the informal cross-section approach, the formal cross-section approach, the panel approach, the time-series approach, and the distribution approach. This is perhaps the most comprehensive and up-to-date survey, but given the importance of the issue, other significant works have also been published, such as Quah (1997b), De la Fuente (1997), Durlauf and Quah (1999) or Temple (1999).

From these surveys it can be seen that there is a substantial body of theoretical and empirical research focusing on the issue of country and regional convergence, and the Chinese case is by no means an exception. Most previous studies have examined convergence across Chinese provinces using parametric techniques which adopt either cross-section or panel data approaches (see, for example, Rozelle, 1994; Jian et al., 1996; Chen and Fleisher, 1996; Raiser, 1998; Yao and Zhang, 2001a,b; Weeks and Yao, 2003; Wang, 2003; Pedroni and Yao, 2006, among others).[111] However, the empirical evidence found in the literature on the subject is rather mixed. For example, Rozelle (1994) found divergence within the Jiangsu province for the 1984-1989 period and Jian et al., (1996, p.8) concluded that during the pre-reform period (prior to 1978) the Chinese provinces tended to diverge, while in the post-reform period (after 1978) until 1990, a tendency towards absolute convergence predominated. Nevertheless, this pattern changed to divergence in per capita incomes from 1990 to 1993. Using cross-section and panel data techniques, Chen and Fleisher (1996) provide evidence of divergence in the pre-reform period and convergence from 1978 to 1993.[112] In contrast, opposite results were found by Weeks and Yao (2003) using the GMM estimator. In addition, despite using different methodological approaches, Yao and Zhang (2001a,b) found that the Chinese regions did not converge in the reform period (1978-1995). Indeed, their results clearly indicated evidence of divergence in the different geo-economic *clubs* (coastal and non-coastal zones). Only when they controlled for regional effects and other determinants of growth did they find conditional β-convergence using the panel data approach (Yao and Zhang, 2001b). More recently, in a study covering the 1952-1997 period and using non-stationary panel techniques, Pedroni and Yao (2006) provided empirical support for the fact that the long-run tendency since the reforms has been for provincial-level incomes to continue to diverge. They added that this divergence cannot be attributed to the presence of separate, regional convergence clubs divided among common geographic sub-groupings such as the coastal versus interior provinces or preferential policies. This ambiguity in the results, of course, depends on the selection of the period under study, the estimation method that is used, the variables that the researcher has considered and, in studies that examine the differences in per capita income among clubs, the *a priori* selection of these small groups of regions could affect the empirical analysis (Maasoumi and Wang, 2008).

In contrast, there is little empirical evidence of convergence across the Chinese provinces using the distribution dynamics model developed by Quah (1993a). Only two recent papers

[111] Studies such as Rozelle (1994), Jian et al. (1996), Gundlach (1997), and Yao and Zhang (2001a,b) did not consider the endogeneity or the dynamics of the models, and were thus in line with the critique stated by Casseli et al. (1996). Only a few works try to deal with this problem, such as Weeks and Yao (2003), Wang (2003) and Ding et al. (2008), among others.

[112] Similar results were found by Raiser (1998) and Wang (2003) for the post-reform period.

apply this new way of analysing economic convergence across the Chinese provinces: Bhalla et al. (2003) and Sakamoto and Islam (2008). The former investigated convergence patterns from 1952 to 1997 using per capita GDP data among Chinese provinces. They concluded that there is evidence of convergence within the predefined geo-economic sub-regions, but no evidence was found of convergence between the sub-regions. In particular, they argued that the gap between the eastern and the central regions was small in the pre-reform period, but widened rapidly in the reform period. The same pattern occurs with the eastern and western provinces, but with a more significant fluctuation over time. These results imply a strong divergence between these two pairs of regions. More recently, the latter authors – Sakamoto and Islam (2008) – found similar results. Indeed, their findings indicated that the distribution of per capita income across Chinese provinces over time has attained a bimodal characteristic with two opposing tendencies in the two sub-periods considered (1952-1978 and 1978-2003). During the pre-reform period the dynamics of the distribution indicated that there were more provinces concentrate at lower values of per capita income, whereas during the post-reform period the dynamics of the distribution moved in the opposite direction, namely, there were more provinces moving towards higher income groups. In spite of these results, Sakamoto and Islam (2008) argued that the distribution dynamics of the reform period do not seem to have led to a stable pattern yet, thus making prediction difficult, and hence it remains an open issue to be analysed further.

This paper examines the complexity of the convergence process in per capita income across the 28 Chinese provinces over the period 1952-2005, which means that our proposal therefore stands with those using the distribution approach developed by Quah (1993a,b). Unlike previous studies that apply either σ- or β-convergence in cross-section or panel data techniques (which sometimes require strong assumptions), we allow data to reveal the nature of the relationship of interest by using non-parametric techniques. It is mainly a data-driven approach and we do not impose any assumption or restriction on the specification of the density of the distribution. So, in its initial steps, our investigation differs only slightly from that conducted by Sakamoto and Islam (2008).

However, we introduce a series of variations with respect to both Bhalla et al.'s (2003) and Sakamoto and Islam's (2008) proposals. Some of the differences we introduce have to do with the fact that the analyses of Chinese income distribution and convergence have dealt with the behaviour of incomes in terms of provinces – i.e. regional convergence. However, as indicated by Jones (1997), while this is a common way to view and analyse data, it can be highly misleading: should provincial borders be drawn differently, conclusions might vary remarkably. Alternatively, we could weight each province by its population (although other weighting schemes are possible) so that the unit of observation was then a person instead of a province. As indicated by Sala-i-Martin (2006), the unweighted approach is not useful if one is concerned about human welfare, since different provinces have varying population sizes. In this regard, the most important fact to note is that, for instance, by 2005 the population living in Sichuan was more than 20 times larger than the population living in Qinghai or in Ningxia. Disparities were even higher by 1952 – the population living in Sichuan was more than 40 times larger than that living in Ningxia. Therefore, the experience of the most populated provinces largely determines what happens to the "average" person in China.

By weighting by population, some researchers have drawn different conclusions to those reached via unweighted analyses. For instance, Jones (1997) showed that the emergence of a bimodal distribution disappeared once each country data point was weighted by population, whereas Schultz (1998) found that, when one uses population-weights, it is no longer true that incomes tend to diverge. Given the disparities in terms of both population and GDP across Chinese provinces, one may expect some interesting conclusions to emerge in the case of China when comparing our results to the unweighted analysis by Sakamoto and Islam (2008).

The distribution analysis approach is also attractive because of its ability to disentangle the existence of spatial spillover effects, in a similar fashion to Quah (1996c). Following this author's approach, we measure whether these spillovers could exist or not by evaluating the magnitude of the contiguity effect across Chinese provinces. The rationale for this lies in the fact that the economic development of a particular region could be strongly related to that of its neighbouring provinces. The issue is particularly relevant in the case of China, whose government considered that by developing the coastal regions, the central and western provinces would also boost their development via (spatial) spillover effects. However, empirical evidence evaluating these policies is still scarce. Only Brun et al. (2002) have conducted research on the issue, their findings indicating a relative failure of the growth of the coastal regions from 1981 to 1998 to trigger development in the western provinces. Therefore, according to these authors, it would be wrong to expect spillover effects to be enough to reduce disparities between Chinese provinces, at least in the short run.

The rest of the paper is organised as follows. Section 2 describes the main trends in provincial distribution of per capita GDP in the Chinese economy during the period under consideration. Section 3 deals with the technical aspects of the distribution analysis model. In Section 4 we analyse the results of applying the model to per capita income data for 28 Chinese provinces. Finally, we present some concluding remarks in Section 5.

4.2. Emerging patterns in provincial distribution of per capita GDP in China: 1952-2005.

A comprehensive description of the evolution of the Chinese economy is beyond the scope of this section and the reader is directed to other studies, such as Lardy (1992), Chai (1998) or Bramall (2000), for more details. Here, we briefly summarise the most important trends of the per capita GDP and population across Chinese provinces during the period under consideration (1952-2005). Table 1 shows the per capita GDP and population of the 28 Chinese provinces in 1952, 1978 and 2005, the growth rates of both magnitudes for the whole period (1952-2005) and for the two sub-periods considered (1952-1978 and 1978-2005), as well as the corresponding standard deviation of all magnitudes reported. As can be seen, there are substantial differences in per capita GDP among provinces in each year, as well as for each province between 1952 and 2005. In 1952 the average provincial per capita GDP in China was 140.86 Yuan and its standard deviation was 78.07 (coefficient of variation of 0.55). Between 1952 and 2005, the per capita GDP of Chinese provinces, measured in constant 1952 prices, was growing at a cumulative average growth rate of 6.39%, the result being that the average provincial per capita GDP reached 4470.46 Yuan in 2005. However, by that year the coefficient of variation had increased to 1. This rapid growth and the increase in regional disparities have two very different steps in time: prior to the economic reforms, i.e. before 1978, and the post-reform period.

The pre-reform period (1952-1978) was characterised by the central planning of the allocation of economic resources and an unstable political environment. China experienced many booms and boosts, like the Great Leap Forward (1958-1961) or the famine caused by failures in the agricultural sector following the unstable economic and political environment that accompanied the Cultural Revolution (1966-1976). Nevertheless, in spite of these turbulences the average provincial per capita GDP grew at a rate of nearly 4%, although regional inequalities increased significantly in that period. During those years the coefficient of variation of provincial per capita GDP increased from the aforementioned 0.55 to 1.19. The existence of barriers across regions (Rozelle, 1994) probably accounts for the divergence rather than convergence in per capita GDP that took place in the pre-reform period. These barriers are to be understood in the broad sense of the term and are notably related with the mobility of workers, the unequal specialisation in the different economic activities of provinces, the promotion of investment in heavy industry rather than in agriculture or the centralised fiscal system (Wei, 1996).

In contrast, in the post-reform period (1978-2005), the average growth rate of the per capital GDP of the Chinese provinces increased to 8.79%, while the provincial inequality in per capita GDP, as measured by the coefficient of variation, declined from 1.19 to 1. This period is characterised by the economic reforms initiated in the late 1970s, including the progressive adoption of market-oriented and open-door strategies for development (that culminated in 2001 with its adhesion to the WTO), and which were gradually transforming the Chinese economy towards a more market-oriented, decentralised and open economy.

To sum up, these stylised facts reflected the most widely extended result in empirical studies, i.e. the absence of convergence or even divergence during the pre-reform period and slight convergence in the post-reform period.[113]

However, a closer look at the data reveals that, even within each sub-period, the dynamics of the first moments of the distribution of per capita GDP were very volatile, especially the variance throughout the first sub-period, but also in the second sub-period.[114] Although in the period 1978-2005, the variability of the variance of the distribution was much smaller, some changes in its trend can also be seen. Between 1978 and the late 1980s and early 1990s, the variance in distribution drops regularly, then the trend changes and increases again almost to the end of the sample (2004). At the end of the sample a new change in the trend of the variance appears indicating a new decrease in the inter-provincial inequality. Table 1 shows that the performances of the provinces in each economic zone (east, central and west) were also very different to each other throughout the period under consideration. Thus, while the provinces in the eastern zone reproduce the aggregate changes in average growth and inequality of per capita GDP on a different scale, in the central and western zones the dynamics varies markedly between them as well as between the two sub-periods. In the pre-reform period the average growth rate of the western provinces was superior to that of the provinces in the central zone (3.87% and 2.66% respectively), this difference being reversed in the post-reform period (7.79% and 8.77%). Furthermore, the dispersion of the provincial growth rates slowed down significantly in the post-reform period in all the zones. At the same time, while the inequality among provinces in the central zone declined throughout the whole of the period considered (the coefficient of variation was 0.42, 0.37 and 0.31 in 1952, 1978 and 2005 respectively), in the western provinces the average inequalities did not change in the pre-reform period and increased significantly in the post-reform period (the coefficients of variation were 0.30, 0.30 and 0.49 respectively). The picture is complex, and when we look at the data in more detail, the more differences we find in the performance of different provinces and zones. In fact, as stated by

[113] See, for example, Bhalla et al. (2003).
[114] We do not report the standard deviation of all the distributions year by year, but they are available upon request.

Quah (1996b, c, d, 1997a), looking only at the first and second moments of the distribution is likely to be uninformative in the case of multimodal distributions, as could be the case, and therefore it is better to analyse the entire distribution of provincial per capita GDP and its dynamics.

4.3. Per Capita income convergence as distribution dynamics

The literature on growth and convergence has debated intensely about the importance of analysing distribution dynamics in order to understand the mechanics of economic development. This view was strongly supported not only by Quah (1993a, 1996b,d) but also by many others who advocate the analysis of the dynamics of the entire cross-section distribution of per capita income (or labour productivity). The reasons for this lie in the fact that uncovering all the information on the dynamics using only summary statistics is a questionable procedure. Accordingly, empirical studies have shown consistent evidence of a cross-country income distribution displaying bimodality with a marked thinning in the middle. This transformation implied that while by the 1960s many countries belonged to the middle income group, by the 1990s the world polarised into two groups, namely the rich and the poor, a phenomenon to which Quah (1996d) refers to as “twin-peak” or “two-club” convergence. However, as indicated by Cetorelli (2002), there is a positive probability of an economy moving from one group to the other, i.e. the bimodal distribution is ergodic. One can therefore observe previously poor economies that grow rapidly and move to join the rich club; reversals of fortune, where fast growth is only temporary and may be followed by abrupt halts and *decumulation*; or economic disasters involving previously rich economies regressing to lower levels of income (Cetorelli, 2002).

The instruments provided by Quah (1993a,b), along with some others borrowed from the literature on income inequality (Shorrocks, 1978), are of remarkable interest for analysing provincial per capita income dynamics in China. Quah’s critique to previous approaches to examining convergence (basically those based on analysing β- and σ-convergence) points out that conclusions are based on (two) summary statistics only. However, both the mean and the standard deviation give an interesting but incomplete illustration of the entire distribution of per capita income, for it conceals some significant features such as the existence of multiple modes. This and related phenomena would be overlooked unless an analysis taking into account different groups of provinces were performed; however, focusing on the entire distribution is even better than carrying out the analysis for different groups of provinces.

4.3.1 Intra-distribution mobility and ergodic distributions

Our variable of interest is the normalised logarithm of per capita income, i.e. divided by the mean for the 28 provinces.[115] We consider this type of normalisation because of the informativeness of its interpretation: the closer a value is to the unity, the closer it will be to the national average. Therefore, the more values there are close to unity, the higher the convergence to this national average will be. Our selected variable is the same as the one chosen by Sakamoto and Islam (2008), but it is normalised in a slightly different way – they use the log of normalised (divided by the mean) per capita income. While it is basically the same variable, we consider that ours has the interesting feature of being more directly interpretable – we can measure, for instance, whether a particular province has twice or half the average. While the normalisation selected by Sakamoto and Islam (2008) provides similar information, it is not as direct. Like Sakamoto and Islam (2008), we denote this variable by x_i, so that $x_i = log\ y_i / log\ \bar{y}$, where y_i is the per capita income of province i, and $\bar{y}$ is the cross-section average of y_i.

[115] For the sake of simplicity, we use the concept of provinces throughout this paper. However, in China there are 23 provinces, 5 autonomous regions, 4 municipalities, and 2 special administration regions (SAR). We have excluded Tibet due to the lack of data. Moreover, this paper focuses on Mainland China, and consequently we have also excluded Taiwan, Hong Kong and Macao. In addition, Hainan is included within Guangdong province and Chongqing is included as part of Sichuan province, given that the former was separated from Guangdong in 1988, and the latter was part of Sichuan until 1997. This is standard practice in Chinese studies. Related to this, there is a debate in the literature about the quality of Chinese statistics. However, it is possible to find support for the quality of the Chinese statistics required to examine the long-run trends in Holz (2005), Chow (2006) and Bai et al. (2006). We use one of the latest and revised compilations edited by National Bureau of Statistics of China (NBS) in 2005 and 2006, which provides us with information that is homogenous enough, both across Chinese provinces and over time, to perform this study properly. More specifically, our main data source is “China Compendium of Statistics, 1949–2004”.

Therefore, in our setting, $s_{i,t}$ refers to province i's normalised per capita income in period t, whereas $F_t(s)$ refers to the cumulative distribution of $s_{i,t}$ across provinces. Corresponding to $F_t(s)$, we can define a probability measure λ_t s.t.:

$$\lambda_t((-\infty, s]) = F_t(s), \forall s \in \mathrm{R}. \qquad (1)$$

where λ_t is the probability density function for each indicator across provinces in period t. Therefore, the model analyses the dynamics of λ_t, i.e. the dynamics of the cross-section distribution of per capita income,[116] for which we consider a stochastic difference equation:

$$\lambda_t = P^*(\lambda_{t-1}, u_t), \text{ integer } t, \qquad (2)$$

In the above equation, $\{u_t$: integer $t\}$ is the sequence of disturbances of the entire distribution, and P^* is the operator that maps disturbances and probability measures into probability measures. In other words, the P^* operator reveals information on how the distribution of per capita income at time $t-1$ (y_{t-1}) transforms into a different distribution at time t (y_t).

Following Redding (2002), we may assume that the stochastic difference equation is of first order and that operator P^* is time invariant. Thus, by setting null values to disturbances and iterating in (2) we obtain the future evolution of the distribution:

$$\lambda_{t+\tau} = (P^* \cdot P^* \cdot \ldots \cdot P^*)\lambda_t = (P^*)^\tau \lambda_t \qquad (3)$$

By discretising the set of possible values of s into a finite number of cells $k \in \{1, \ldots, K\}$, P^* becomes a transition probability matrix:

[116] From now on, when talking about per capita income we will be referring implicitly to normalised log of per capita income.

$$\lambda_{t+1} = P^* \cdot \lambda_t \qquad (4)$$

In this transition probability matrix, λ_t turns into a $K \times 1$ vector of probabilities that a given province per capita income is located in a given grid at time t.

Discretisation divides the space of possible Ft values into discrete grid cells (what some authors call "states" or "classes") e_k, $k = 1, \ldots, K$. Then, after classifying each country-year observation into one of the K states, we build up a 5×5 matrix whose p_{kl} entries indicate the probability that a country that is initially in state k will transit to state l during the period or periods considered (T). Each row of the matrix constitutes a vector of transition probabilities, which adds up to unity. The boundaries between grid cells are chosen so that country-year observations are divided approximately equally among the cells, each cell corresponding to approximately one fifth of the distribution of the selected variable across provinces and time. Interpretation is straightforward: observations in the first state refer to the poorest provinces. This way of constructing is common practice (see, for instance, Redding, 2002; Lamo, 2000). Some other contributors have considered different criteria such as selecting the limits between states arbitrarily, although reasonably (Kremer et al., 2001; Quah, 1993a). Alternatively, it is possible to dodge the discretisation problem by considering stochastic kernels (Quah, 1996c), although these present some difficulties for estimating the ergodic or stationary distribution.

Transition probability matrices make it possible to measure the probability of a given province moving to a higher (or lower) position on the grid. Calculating the transition probability matrices starts by discretising the set of observations into the selected states e_k. The interpretation of the different figures in each matrix is straightforward. In the case of the limits between states, those for which e_k = (0.25, 0.50) would include provinces whose per capita income ranged between one quarter and half the national average. In the case of the different entries in the matrices, they indicate the probability of a given province transiting out from its initial state to other states during the period or periods considered.

To compute each transition matrix, we count the number of transitions out of and into each cell, i.e. for each p_{kl} cell:

$$p_{kl} = \frac{1}{T-1}\sum_{t=1}^{T-1}\frac{n_{kl}^{t}}{n_{k}^{t}} \tag{5}$$

where T is the number of years or periods, n_{kl}^{t} is the number of countries moving during one period from class k to class l, and n_{kl}^{t} is the total number of provinces starting the period in class l.

According to this methodology, transitions are estimated by counting the number of provinces moving from one class to another. However, as indicated in the introduction, using provinces as units of analysis would not be useful if we were concerned with human welfare because different provinces have different population sizes. Therefore, the unweighted analysis does not help to answer questions such as "How many people in China live in poverty?" or "How have poverty rates changed over the last few decades?" Therefore, it is also relevant to estimate weighted transition probability matrices, for which different weighting schemes are feasible, and are not limited to just population. The underlying idea is that the impact on Chinese per capita income will be greater if a larger country transits out than if a small province does so. Therefore, we count provinces' transitions, but in this case each province is represented by its entire share of Chinese population (in the case of population-weighted transition probability matrices), so that the unit of observation is now a person instead of a country, i.e. we count the number of persons moving between states. This issue is often ignored, although exceptions do exist, such as Kremer et al. (2001) or Jones (1997).

By operating with the information offered by the transition probability matrix we can also characterise the hypothetical long-term ergodic or stationary distribution. The variety of resulting scenarios might be remarkable, including distributions with the probability mass concentrated mainly in the central classes (indicative of convergence to the mean if these central states contained the unity), polarised distributions ("twin peaks") indicating that the poorest and richest are becoming increasingly more distant from each other, or one with the probability mass distributed in the extreme classes (tails) of the distribution. Therefore, the ergodic distributions make it possible to determine the predominating long-run tendency for provincial per capita income in China.

4.3.2 Transition path analysis and mobility indices

We can also evaluate the speed with which the ergodic distribution, or steady-state, is approached by means of the concept of asymptotic half life of the chain, $H - L$, which is how long it takes to cover half the distance from the stationary distribution. Following Shorrocks (1978), the half life is defined as:

$$H - L = -\frac{\log 2}{\log |\lambda_2|} \qquad (6)$$

where $|\lambda_2|$ is the second largest eigenvalue (after 1) of the transition probability matrix. It ranges between infinity – when the second eigenvalue is equal to 1 and the stationary distribution does not exist – and 0 – when $\lambda_2 = 0$ and the system has already reached its stationary equilibrium (Magrini, 1999).

We also consider the mobility indices proposed by the literature on economic inequality (Shorrocks, 1978; Geweke et al., 1986). As suggested by Quah (1996a), analogously to the measures of income inequality designed to collapse the information contained in an entire distribution into a single scalar, a mobility index summarises the mobility information in a transition probability matrix into one number. We consider the proposals by Shorrocks (1978) and Geweke et al. (1986), summarised by Quah (1996a). In their proposals, by defining the mobility index as a continuous real function $\mu(\cdot)$ over the set of transition matrices P, it satisfies the properties of normalisation, monotonicity, immobility, and perfect mobility (see Shorrocks, 1978). This index (μ^1) evaluates the trace of the transition probability matrix, disclosing information on the relative magnitude of diagonal and off-diagonal terms. It is identical to the inverse of the harmonic mean of expected durations of remaining in a certain state and, following Quah (1996a), its particular expression is:

$$\mu_1(P^*) = \frac{K - \mathrm{tr}(P^*)}{K-1} = (\frac{K}{K-1})\{K^{-1}\sum_j (1-P_{jj}^*)\} = \frac{K - \sum_j \lambda_j}{K-1} \tag{7}$$

where K is the number of classes, P_{jj}^* is the j-diagonal entry of matrix P^*, which represents the probability of remaining in state j, and λ_j represent eigenvalues of P^*. Large values of μ_1 indicate less persistence (or more mobility) in P^*.

4.3.3 The evolution of the external shape of the distribution

It is also relevant to provide information on both the initial and final distributions for the variable of interest, in order to gain further insights into how distributions have evolved. Therefore, for all indicators we provide four sets of additional results, namely, transition probability matrices, ergodic distributions, initial distributions, and final distributions.

However, in their present form, the three sets of distributions share a common disadvantage, namely, they are discrete and probability is spread out across one set of states only. Although we have provided reasons why such a disadvantage may not be as restrictive as some authors suggest, we try to be as informative as possible by also providing the continuous counterpart to this discrete estimation, namely, the non-parametric estimation of density functions via kernel smoothing. This is the first step in Quah's model of distribution dynamics, and it provides remarkable insights about the convergence process. If the probability mass became tighter, it would indicate convergence, whereas if it became flatter, it would be indicative of divergence. As can be easily inferred, multiple scenarios may result.

We consider a kernel estimator for each indicator:

$$\hat{f}(x) = \frac{1}{Nh}\sum_{i=1}^{N} K(\frac{\|x - X_i\|_x}{h}) \tag{8}$$

where x is the point of evaluation, X is the indicator of interest, N is the number of observations (countries), h is the bandwidth, $\|\cdot\|_x$ is a distance metric on the space of X, and $K(x)$ is a kernel function (see Härdle and Linton, 1994) which are generally required to hold that:

$$\int_{\mathrm{R}} K(x)dx = 1, \quad \int_{\mathrm{R}} xK(x)dx = 0, \sigma_K^2 = \int_{\mathrm{R}} x^2 K(x)dx < \infty \tag{9}$$

There are several choices for $K(x)$, which may be defined in terms of univariate and unimodal probability density functions. For the sake of simplicity, we consider a Gaussian kernel:

$$K(x) = (1/\sqrt{2\pi})e^{-\frac{1}{2}x^2} \tag{10}$$

Weighting densities (in order to provide continuous counterparts to the weighted initial and final distributions) requires slight modifications. Few studies have considered this, despite its potential relevance in some specific contexts. Following Goerlich (2003), expression (8) is slightly modified to become:

$$\hat{f}_\omega(x) = \frac{1}{h}\sum_{i=1}^{N}\omega_i K(\frac{\|x - X_i\|_x}{h}) \tag{11}$$

where ω_i is the share of either world output or world population (depending on the type of weighting we consider) corresponding to country i.

The continuous version of the ergodic distributions is more difficult to estimate. In this case, related literature is scarce. Some studies provide estimations for ergodic densities (see Johnson, 2000, 2005). However, no studies provide, simultaneously, results for ergodic distributions yielded by transition probability matrices and ergodic densities. In order to obtain a fully compatible view between the results of the transition probability matrices and their continuous counterpart, we generated ergodic densities considering the information in the (discretised) ergodic distributions (1×20). Specifically, we generated normal distributions for each of the twenty states over which probability is spread out, with a number of observations proportional to each state's share of ergodic probability. This generates a pseudo-histogram in which we do not have bars, but normal distributions. Then we proceed in exactly the same way as when smoothing both initial and final distributions, i.e. by considering kernel methods to smooth the observations in each of these twenty states. This algorithm yields ergodic densities which are fully consistent with the ergodic distributions computed from transition probability matrices. The continuous state approach naturally complements the view provided by discrete ergodic distributions, which tend to summarise too much information in a few states. Although the information provided by ergodic densities is essentially the same, we remove the arbitrariness implied by selecting a grid.

4.3.4 Conditioning on neighbour-relative information

The techniques employed enable us to analyse the importance of spatial factors in explaining regional convergence or divergence. In particular, following Quah (1996c), we can analyse the role played by surrounding regions in explaining the dynamics of regional distribution of per capita GDP (conditional distribution dynamics). The specific hypothesis to be tested is whether Chinese provinces might be converging with their neighbours, i.e. the provinces around them. Quah (1996c, 1997a) provides reasons as to why such a convergence pattern could exist, along with methods to evaluate conditional convergence with our instruments. As indicated by Quah (1996c), and most of the literature on spatial economics, geographical location and spatial interactions between regions *matter*. Increasing returns to scale, together with enhancing market access, and probably a combination of labour migration across regions and vertical linkages between industries explain the cumulative process of regional growth, which endogenously turns into a polarisation of the spatial distribution of per capita income.[117] Additionally, the existence of localisation and urbanisation economies, or knowledge spillovers, reinforces the

[117] From the pioneering work of Marshall (1890) to the more recent developments of the "new economic geography" (Krugman, 1991, 1993), economists have emphasised a combination of these forces to explain the strong localisation of economic activity.

capacity of areas surrounding more highly developed regions to grow. Not only geographical location but also proximity matters for growth. As can be seen in Table 1, the Chinese provinces with higher growth rates of per capita GDP between 1978 and 2005 (over 9%) are all next to each other and stretch almost continuously from Liaoning in the northeast to Guangdong in the southeast and to Sichuan in the west. Liaoning, Hebei and Shandong are provinces located around Beijing and Tianjin; Zhejiang is located between Shanghai and Fujian; while Guangdong and Fujian are located next to Hong Kong, Taiwan and Shanghai. This set of coastal provinces also stretches westward through Anhui, Henan, Hubei and Sichuan. Proximity, or even the neighbourhood, could become a key factor in its growth. In order to elucidate the existence and magnitude of these spatial spillovers, we conducted an analysis which hinges on the comparison of two income series: (i) state-relative income, where we normalise each province's per capita income by the per capita income in China (which are the data used to conduct the analysis in the previous subsections); (ii) and neighbour-relative income, where we normalised each province's per capita income by the average per capita income of the surrounding, physically contiguous provinces, excluding the province itself. As indicated by Quah (1996c), it is convenient to consider these two relative income series as the parts unexplained by nation-state factors and physical-location factors, respectively. Thus, we conduct the same analyses as those presented in subsections 3.1–3.3 to this new series of neighbour-relative income, focusing on the comparison with the state-relative income series. Interpretations are also straightforward: the closer the values of the neighbour-relative series are to unity, the lower the inequalities among neighbour provinces will be and, therefore, the higher the magnitude of the spillover effects will also be. From this, it can easily be inferred that comparing these two series would be equivalent to analysing unconditional versus conditional convergence.

4.4. Results

Results concerning both transition probability matrices and ergodic distributions are reported in Tables 2 to 5. They constitute a total of 12 panels in which different sorts of related information are reported. The four different tables present results for the different sub-periods considered, i.e. the first panel in each table provides results for the entire 1952-2005 period, whereas the second and third panels provide results for the periods 1952-1978 and 1978-2005 respectively. Furthermore, apart from the analysis of the unweighted distribution of per capita income, the additional conditioning schemes commented on in the introduction are also considered (GDP-weighted, population-weighted and physically-contiguous conditioned). In addition, the last three rows in each panel display information on the initial, final and ergodic distribution of the variable under analysis.

4.4.1. Unweighted analysis

Table 2 reports on unweighted transition probability matrices for all the periods considered. In each of the matrices contained in the table, the upper limits have been set to the same values in order to make comparisons possible. The criterion to specify the grid is the one usually found in the literature (see, for instance, Lamo, 2000), i.e. considering all observations for the entire period 1952-2005 (28 observations per year and 54 years, which totals 1512 observations), we divide them into five equally-sized intervals. The limits of the grid are displayed in the first row of each panel. Their interpretations are straightforward: the upper limit for the first state is 0.919, indicating that approximately one fifth of the total number of observations lay below that threshold – i.e. below 91.9% of the average. At the other extreme, the upper-state has observations lying above 1.061 (106.1%) of the average. Note that the average is unity, since our data have been normalised by the mean: the closer a value is to the unity, the closer it is to the average for its particular year.

The contents of each matrix in Table 2 have some commonalities with the concept of β-convergence, since they provide information about intra-distribution mobility, or churning

(Quah, 1996c). Each cell in the matrices must be interpreted as the probability of remaining in that particular state after five years (recall that we compute 5-year transitions). For instance, the upper-left entry of the matrix in Table 2.a would indicate that the probability of the observations in the lowest relative per capita income state (below 0.919) remaining in that state was 82%, whereas the remainder moved up to higher relative income states. Persistence was even higher at the other extreme of the distribution, as revealed by the lower right cell in the matrix, which indicates that 89% of the observations in the highest relative income state remain in the same class after five years. The other values in the main diagonal show a higher degree of mobility. For instance, entry a_{22} would indicate that, after 5 years, only 62% of observations remain in the same state of relative wealth, whereas 15% move down to lower per capita income states and the remaining 23% move up to higher per capita income states. In general, values in the main diagonal closer to 1 indicate more persistence, whereas values closer to zero indicate higher mobility.

In the matrices examined in Table 2, values on the main diagonal average 0.72, 0.62 and 0.81 for the periods 1952-2005, 1952-1978 and 1978-2005, respectively. This information is rich, but it would be richer still if additional ways of evaluating persistence/mobility such as the mobility indices presented in Equation (7) were considered. The results of these indices are shown in Table 6 and, in general, they corroborate what the averages for the diagonal entries revealed, i.e. the sub-period 1952-1978 shows much higher mobility than that of 1978-2005 (0.737 vs. 0.605) and, for the whole period, total mobility lies somewhere in-between (0.674). However, as will be shown below, it is not only the intensity of mobility that differs across periods but, more importantly, its sign; mobility leads to probability mass concentrating at lower states in the first sub-period, whereas the pattern is the opposite for the second one.

The last three rows in each table support this claim. They contain information on the initial (1952), final (2005) and ergodic (steady-state) distributions for the three periods considered. Table 2.a indicates that the initial and final distributions do not differ strongly. What is more revealing is that, under current trends, the ergodic distribution will be almost uniform, with the same probability in each state. However, we must bear in mind that in our particular setting *under current trends* may be a misleading statement, since trends have differed remarkably before and after the reform. The ergodic distributions in Table 2.b (pre-reform) and Table 2.c (post-reform) differ notably, not only compared to the ergodic distribution in 2.a but more notably with respect to each other. For the pre-reform period (1952-1978) the ergodic distribution skews towards the left tail of the distribution, whereas the opposite is found for the post-reform period (1978-2005). This would imply that the effects of the reform were positive for convergence among provinces and they are likely to continue over time, indicating that, under 1978-2005 trends, the two states of highest relative per capita income will contain 64% of the provinces.

It is relevant not only to compute the values of the steady-state distribution but also to analyse the speed at which it is approached. As indicated in previous sections, this can be evaluated via the concept of the asymptotic half life of the chain, i.e. the amount taken to cover half the distance from the ergodic distribution (Magrini, 1999). Therefore, computing Equation (6) leads to the results in Table 7. As one might expect *a priori*, although the steady-state reached considering only 1978-2005 information (Table 2.c) is more favourable than that obtained using 1952-1978 information (Table 2.b), it will take much longer to reach the former, in fact, virtually twice the time. This is the result of the higher intra-distribution mobility found for the pre-reform period, as revealed by Table 6. Therefore, although the future predicted using only 1978-2005 information is far more promising, it will take longer to reach it.

Bulli (2001), Johnson (2000, 2005) and many others have pointed out that it may be problematic to consider a discrete approach in which probability is split in some states whose limits are somehow arbitrary. Sakamoto and Islam (2008) partly circumvent this criticism and add some additional robustness to their analysis by considering different grids (5 and 7 grids), the results being similar for the different choices. We believe it is more interesting to consider a *fully* continuous approach, in which continuous counterparts to the initial, final and steady-state distributions in Table 2 are provided.

Figure 1.a displays the continuous counterparts to the discrete initial (1952) and final (2005) distributions in the tables corresponding to the unweighted analysis. Although the densities

basically corroborate the results of the discrete analysis, we can perceive more clearly that, although convergence has taken place (the 2005 density is tighter), we can also see that by 1978 the distribution became bimodal. Therefore, there are some provinces whose performance in terms of per capita income was much better than the rest. Figure 5.a displays the continuous counterpart to the steady-state distributions in Tables 2.b and 2.c. Although results are generally corroborated, some subtleties that the 5-grid analysis could not show are perceived. These are basically related to the multi-modality that will prevail regardless of the sub-period that is considered to construct the steady-state distribution. Taking into account the pre-reform information, the ergodic density (solid line in Figure 5.a) would be basically unimodal, but some very rich provinces (upper tail of the distribution) will coexist with some others (fewer) that are very poor (lower tail of the distribution). This extreme behaviour will fade away if only post-reform information (dashed line in Figure 5.a) is considered, although we can still distinguish two bigger modes – twin peaks, to use Quah's (1996d) term for them.

Therefore, the results obtained by Sakamoto and Islam (2008) are generally corroborated, but we have complemented them in several ways. Although their way of normalising differs, they use a slightly shorter time period (1952-2003) and they add some robustness to the analysis by considering a different number of grids, we find the same broad results, i.e. divergence before the reform and strong convergence afterwards. However, the mobility indices, transition path analysis and continuous approach to the steady-state distributions all enrich the analysis.

4.4.2. Weighted analysis

The analysis performed in the previous section is relevant, but it might be judged as being partly biased because the same importance is attached to all provinces, especially if we are concerned about human welfare – the different provinces have different population sizes. As indicated in the introduction, the unweighted analysis could be highly misleading if we drew national borders differently, as this would affect the shape of the densities. It may be more natural to attach a weight to the observations, where the weights reflect the contribution of each observation in the sample. As indicated in previous sections, we will consider different weighting schemes, i.e. population and economic size (GDP). In the case of countries, both variables are very unevenly distributed. This is especially blatant in the case of population, for which India and China, two of the poorest countries in terms of per capita income, account for more than one third of the total population in the world, whereas some of the richest countries, such as Iceland or Luxembourg, account for only 0.01% of the world population (Goerlich, 2003). In our particular case, it does not seem fair either to treat all Chinese provinces equally in the estimation. As can be seen on the right-hand side of Table 1, there is a significant dispersion in the population of the different provinces. More important still, there has been an important dispersion in the growth rates of provincial population throughout the period analysed, with coefficients of variation in the average growth rates of the provincial population between 0.525 in the pre-reform period and 0.966 in the post-reform era. These differences and changes in the distribution of provincial population have relevant implications when we are looking at per capita distribution of GDP from an individual or personal welfare perspective instead of from a provincial point of view. For example, by 2005, as indicated in Table 1, the population in Sichuan was 110,060,000 (larger than any European country), whereas that of Qinghai was 5,430,000. Therefore, the welfare implications of Sichuan converging with the rest of the provinces are not the same as if Qinghai converged, because of the number of people involved.

Results are shown in the GDP-weighted and population-weighted panels in Tables 3 and 4 respectively. The mobility indices, transition path analysis and continuous analysis are reported in the same tables and figures as those corresponding to the unweighted analysis. Both Tables 3 and 4 offer new perspectives on the evaluation of convergence. Although the unweighted analysis did not predict convergence or divergence (in accordance with the ergodic distribution), the weighted analyses did yield different results. Under the population-weighted scenario (Table 4), according to which we evaluate transitions of people moving across classes, considering the entire period (1952-2005), the steady-state distribution has more than half of the probability mass (56%) in the two upper states. This indicates that a large part of the *population* will escape from poverty in the long run. However, similarly to what we obtained for the unweighted analysis, the tendencies differ remarkably between the pre- and post-reform sub-periods, and it is the effect of the second sub-period which drives the convergence pattern most. As shown in Table 4.b, although the predicted pattern using the 1952-1978 information was convergence, most of the population was being driven deep down into poverty, since the probability mass is overwhelmingly accumulated (72%) in the lowest relative per capita income states. This result is shared when weighting by economic size (Table 3.b), i.e. the largest provinces in terms of GDP were becoming relatively poorer. In contrast, the post-reform period shows opposite patterns. As Table 4.c reveals, in the hypothetical long run (i.e. under 1978–2005 trends) most of the population (94%) will reach the two highest per capita income states, and only 2% will remain in the poorest class. An analogous result is found when weighting by GDP (94% probability in the two wealthiest states), thus also indicating that large provinces in terms of GDP are also the ones that are escaping from poverty.

Although the general tendency when weighing by GDP or by population is similar for both sub-periods, differences persist when evaluating the implied mobility in each matrix (Table 6) or the half-life time of convergence (Table 7). Regarding the latter, results are very similar to the unweighted case, while for the former some differences emerge. It is when weighting by GDP that convergence is faster in the post-reform sub-period, whereas this occurs in the first sub-period when weighting by population.

Finally, the continuous analysis in Figures 1 and 5 further corroborates how relevant it is to perform the weighted analysis. Figure 2 and Figure 3 report information already displayed in Figure 1 in a different way so as to facilitate an easier visualisation of the patterns. As shown in Figure 1.b and Figure 1.c, and particularly in Figures 2 and 3, the evolution of the shape of the weighted densities differs compared to the one shown in Figure 1.a, especially in 2005. Weighting by GDP makes the density shift rightwards (Figure 2.c), although some additional bumps emerge, thus indicating that some important shares of GDP will remain in poor provinces. The result of weighting by population is more striking, since it indicates that by 2005 a large share of the population was reaching higher income levels, but a larger share was also trailing behind, as indicated by a marked bimodality. This is what Quah (1996d) refers to as twin peaks. However, in the steady-state (Figures 5.b and 5.c), and confirming what we found via the discrete analysis of the transition matrices, much of this bimodality will fade away and the distributions will be basically skewed rightwards when using 1978–2005 information, which contrasts sharply with the bimodality found for the unweighted case (Figure 5.a).

In synthesis, uneven distribution of per capita GDP across Chinese provinces becomes less strong when weighted by GDP or population, that is, in terms of average personal welfare, and when using the post-reform information the implicit steady-state distributions will be skewed rightwards and reflect an improvement in the symptoms of convergence. Nevertheless, some peaks persist on the right-hand side of the distribution and it will also take a long time to reach the steady state. These stylised facts, together with the variability and changes of the trend in the variance of the distribution mentioned above, are quite consistent with the timing of the reforms, the unbalanced regional implications of these reforms and with the changes of emphasis in the main policy objectives during the period.

In the first phase of the economic reforms, but before economic liberalisation, the strategy was concentrated on the rural areas. The commune system was removed in favour of the Household Responsibility System, where workers were allowed to operate on their own, although with some restrictions.[118] After decollectivisation, the Chinese government promoted economic policies addressed to diversify agriculture, especially by enhancing the rural industries and the township and village enterprises (TVEs). In fact, the promotion of TVEs was the most important way to transfer excess rural labour into industrial production, given the strong restrictions on interprovincial migration (Fujita and Hu, 2001). As a result, rural industrial output increased sharply in this period. However, the effectiveness of TVEs also raised some doubts owing to the fact that they often operated according to non-economic criteria in the early years of the reforms. Some regions improved in this phase, especially those oriented towards industry, but the income differentials persisted among provinces given the barriers that existed across provinces (Rozelle, 1994).

[118] Further details on rural reforms and agricultural growth can be found in Lin (1992).

In the 1980s, the second phase of the reforms was characterised by the gradual opening up of the Chinese economy, the increased presence of the non-state sector (collective and private sectors) and a fiscal reform that endowed the provinces with more fiscal power (Wei, 2003). At first the open-door policy was especially favourable for the coastal areas (open cities and Special Economic Zones – SEZs). Thus, the geographic and economic policy factors allowed trade and FDI to become concentrated in the coastal areas.[119] At the same time, this period was distinguished by a major liberation and decentralisation of the economy compared with the previous stage. For example, price liberalisation accelerated the entry of non-state enterprises, and the profit-oriented incentive schemes in state industry led to a rapid increase in industrial output and gains in productivity by the mid-1980s. As a result the non-state sector gradually became more important in the economic development of China.[120] Although the interprovincial mobility of workers was still costly, there was an increase in migrational movements from rural areas to urban and coastal areas. On the other hand, the fiscal decentralisation of 1980 played a key role in improving the autonomy of local governments, but generated a significant budget deficit. Consequently, the fiscal system was reformed in 1985. The immediate effect of this reform was a reduction in the central government's ability to redistribute revenues among regions, which together with the economic developments that favoured coastal provinces, increased symptoms of divergence and led to a new fiscal reform in 1994. The main feature of this reform was the separation of the national tax service from the local tax service, with an additional mixed category that was shared between central and local government without negotiation and applied to all the provinces with the aim of reducing the income gap across provinces.

[119] Although FDI was allowed in 1979, the effects on output are more significant in the 1980s and 1990s.

[120] Further details about the effects of the reform on the performance of the Chinese State Enterprises can be found in Li (1997).

In 1995, the Chinese government recognised that:

> "S*ince the adoption of reforms and open-door policies, we have encouraged some regions to develop faster and get richer, and we have advocated that the richer should act as a model for and help the poor. Each region has had immense economic development and the people's standard of living has had great improvement. But for some reasons, regional economic inequalities have widened somewhat*" (People's Daily Overseas Edition, October 5, 1995, p. 4.)

Thus, the strategy was changing in favour of promoting a more evenly balanced regional development, in an attempt to reduce the tendencies towards uneven regional development. This strategy became evident in the Eighth Five-Year Plan and, more especially, in the Ninth Five-Year Plan (1996-2000). The Chinese government launched a strategy to promote the development of the central and western regions that relied, at least partly, on the spillovers generated by the more developed coastal provinces.

4.4.3. Conditioning: Spatial analysis

The transition probability matrices in Table 5 show neighbour-relative counterparts to the transition probability analysis carried out for weighted and unweighted state-relative series (Tables 2, 3 and 4). Likewise, the neighbour-relative analysis indicates that conclusions differ notably prior to and after the reform, i.e. they hinge critically on whether we base the future projections (ergodic distributions) on 1952–1978 or 1978–2005 information.

If the entire period 1952–2005 (Table 5.a) is considered, the diagonal entries average 0.708, which is lower than the 0.718 corresponding to the state-relative series (Table 2.a). The mobility indices in Table 6 corroborate this finding, since μ_1 = 0.674 in the case of the state-relative series and μ_1 = 0.695 when conditioning by neighbours' information. Under these trends, the (slightly) higher mobility would lead to an apparently multi-modal ergodic distribution, but it is difficult to discern tendencies. The analysis for the different sub-periods shows, once more, different patterns. The ergodic distribution corresponding to the 1952–1978 trends indicates that multi-modality will prevail in the future. Multi-modality vanishes if we focus on 1978–2005 trends (Table 5.c). In both cases, but especially for 1978–2005 trends, the ergodic distribution differs remarkably when compared to state-relative information (Tables 2.c, 3.c and 4.c), since the probability mass does not entirely abandon the central states. However, as indicated by the asymptotic half life of convergence in Table 7, the ergodic distribution will be achieved much faster when conditioning by neighbouring information, i.e. *conditional* convergence will be faster.

Figure 1.d and Figure 4 also show the impact of conditioning on neighbouring-province information. Although the information contained in Figure 4 was already reported in Figure 1.a and Figure 1.d, the way it is presented allows a clearer understanding of the effect of spatial conditioning. Both Figure 1.d and Figure 4 show tighter distributions for neighbour-relative compared to state-relative per capita income series. This would indicate that each province's per capita income is closer to the average of its surrounding provinces than to the national average, thereby suggesting that spatial spillovers do matter. Yet some subtleties also exist. For instance, the unimodal state-relative distribution of per capita income turns into a tighter but multi-modal distribution when conditioning by neighbouring information (Figure 4.c). This implies that, although the general tendency is towards convergence within spatial clusters, there are some provinces which outperform their neighbours, constituting a remarkable mode in the vicinity of 1.2 (Figure 4.c). Figure 4.c also shows how misleading it may be to draw conclusions based on summary statistics only. The implicit standard deviation of the state-relative series in Figure 4.c is 0.087, whereas that of the neighbour-relative series is higher (0.090), thus indicating more dispersion and, in principle, a flatter distribution. However, the driving force of the higher dispersion that is found is the increasing multi-modality. Therefore, spatial spillovers are relevant, but not for everyone.

Figure 5.d reports continuous counterparts for the ergodic distributions in Tables 5.b (solid line) and 5.c (dashed line). The solid line in Figure 5.d, corresponding to 1952–1978 trends, shows several modes, the biggest one in the vicinity of 1, but another two at the tails of the distribution. The dashed line indicates that the ergodic distribution that would prevail under 1978–2005 trends would be much tighter, in the vicinity of 1, thus indicating that the members of spatial clusters will be quite similar in terms of per capita income. However, several modes

will lie in the upper tail of the distribution, thus indicating that, in the hypothetical long-run scenario, some provinces will still outperform their neighbours, i.e. although there will still be inequalities that cannot be explained by physical-location factors, they will affect provinces differently.

These results, and especially the tendency towards the stratification of provinces in different clubs, are of no minor concern to authorities, and reveal that there is still some room for policies promoting convergence in per capita GDP among Chinese provinces, because the natural tendency to spatial agglomeration seems to be persistent. Thus, together with the explicit regional policies and the use of other central government policies to rebalance regional development (central investment projects, endowment of infrastructures, credit policy, etc.), other measures are also needed to balance the tendency towards the localisation of economic activity induced by market forces. Improvements in the accessibility and the role of market mechanisms in the interior are needed, but increasing the role assigned to official interprovincial migrations is probably necessary too.

4.5. Conclusions

Nobody doubts that the acceleration of the economic reforms initiated at the end of the 1970s have encouraged economic growth over the last four decades. The open-door policy, with a strong drive towards industrialisation focused on foreign investment, especially in the coastal regions, along with a series of economic reforms oriented more towards the market, probably explained this exceptional performance during the 1980s and 1990s. In 1995, however, the Chinese government recognised that the income gap between western and central regions and the coastal areas was increasing, thus making it necessary to implement proactive policies to reduce these inequalities. The stimulus package that was carried out was focused mainly on the development of inland provinces through the promotion of investment as a way to reduce those imbalances.

Accordingly, a plethora of research studies have examined not only the aggregate growth of the country but also other related questions, such as whether differences in per capita income across provinces exist, along with the evolution of disparities over time. This ample body of literature analysing convergence across Chinese provinces continues to grow, examining such relevant topics as those examined by the country and regional convergence studies. Some papers have analysed provincial convergence following the early proposals of Barro and Sala-i-Martin (1992), i.e. by examining β- and σ-convergence, together with some of the ulterior refinements of these techniques. Some others (fewer) have leaned towards the distribution dynamics model initially proposed by Quah (1993a,b). Our article follows this second line of research. Recent contributions, such as Bhalla et al. (2003) or Sakamoto and Islam (2008), have applied Quah's basic proposals to examine provincial convergence in per capita income. Our paper complements their methods and findings and extends them in several directions.

Similarly to Sakamoto and Islam (2008), the ergodic distributions obtained using either pre-reform or post-reform information are quite different, a positively skewed distribution being produced for 1952–1978 and a negatively skewed one for the period 1978–2005. Therefore, it would be corroborated that the post-reform policies have led most provinces to escape from relatively low per capita income levels. However, this analysis has some limitations, such as the need to specify a discrete grid with a limited number of states. Few contributions try to fix this by considering a continuous state space approach (Johnson, 2000). We follow Johnson's (2000) approach to provide continuous counterparts to the ergodic distributions yielded by transition probability matrices, which offered more detailed results. Under both pre- and post-reform information, the hypothetical long-run scenario shows multi-modality. For the 1952–1978 information, the distances separating the biggest modes are quite large, with predominance of a large mode comprising most of the provinces with incomes close to the average, and a small group of provinces that are becoming very rich. However, using 1978–2005 information, these two modes become more balanced, with one of them above the national average and the other one below it. We can also corroborate Sakamoto and Islam's claim that "the dynamics of the post-reform period do not yet seem to have settled into a stable pattern". In our case, the analysis of the asymptotic half life of convergence indicates that it will take much longer to reach the steady state under 1978–2005 trends. Under this scenario, although most provinces will escape from relative poverty, it will take longer because of more complex intra-distribution dynamics.

We extend the analysis to control for some relevant characteristics of Chinese provinces. Specifically, although unweighted analysis of country/regional convergence is commonplace, weighted analysis is far less widely extended. However, in many circumstances and especially if we focus on human welfare (Sala-i-Martin, 2006), weighted analysis might be more relevant than its unweighted counterpart. Several weighting schemes are possible, but because of their significance we considered the population and economic size (GDP) of each province. As stressed throughout the article, since both population and GDP differences across Chinese provinces are outstanding, controlling for these differences might alter the results substantially – which in fact turned out to be the case.

For the entire period 1952–2005, we find that under the population-weighted scenario, the steady-state distribution has more than half of the probability mass (56%) in the two upper states, thereby indicating that much of the population will escape from poverty in the long run. As expected, the tendencies differ remarkably between the pre- and the post-reform periods, and it is the effect of the second sub-period (1978-2005) which, for the most part, drives the convergence pattern. Specifically, for the pre-reform period, although the predicted pattern was convergence, most of the population was being driven deep down into relative poverty, since probability mass is overwhelmingly accumulated (72%) in the lowest relative per capita income states. This result is shared when weighting by economic size. However, the continuous ergodic distributions also indicate that some provinces will still be much richer than the rest, as indicated by the existence of several bumps well above the unity. In contrast, the post-reform period shows opposite patterns. In the hypothetical long run (under 1978-2005 trends) most of the population (94%) will reach the two highest per capita income states, and only 2% would remain in the poorest class. An analogous result is found when weighting by GDP (94% probability in the two wealthiest states), thus indicating that large provinces in terms of GDP are also the ones escaping from poverty. Moreover, when weighting by GDP, convergence is faster in the post-reform period, whereas this occurs in the first sub-period (1952-1978) when weighting by population. Thus, the marked bimodality yielded by the unweighted analysis turns into a tighter pattern of convergence when weighting by population of each province or economic size, as suggested by Sala-i-Martin (2006).

Finally, our study also analysed whether spatial spillovers exist. Although a more thorough analysis would be welcome, the techniques we use can be easily adapted to provide some insights into the magnitude of these effects. This can be thought of as a conditional convergence analysis, in which a province is only compared with its contiguous provinces, and therefore it could converge towards its neighbours' average (conditional, club or cluster convergence) instead of towards the national average (unconditional convergence). Compared to the unweighted, unconditional analysis, the long-run scenario will be multi-modal under pre-reform trends – in fact, we could even talk of club divergence. However, under post-reform trends, cluster convergence will be much stronger, with probability mass concentrating tightly around unity as indicated by the ergodic density; provinces will converge strongly with their neighbours, although some amount of multi-modality will still prevail.

According to our results it seems that all the reforms have enabled poorer regions to gradually converge with the richer ones in the post-reform period, while in the pre-reform period no convergence was found. However, more economic reforms are needed in this regard to guarantee balance and steady economic growth, thereby improving the standards of living of the whole population.

Appendix 4A

Table 1: Descriptive statistics for Chinese provinces, per capita income (GDP/N) and population (N), 1952 to 2005

Province	Y/N[a]			Y/N annual growth rates (%)			N[b]			N annual growth rates (%)		
East	**1952**	**1978**	**2005**	**1952-78**	**1978-05**	**1952-05**	**1952**	**1978**	**2005**	**1952–78**	**1978–05**	**1952–05**
Shanghai	430	2,944	23,583	7.68	8.01	7.85	573	1,098	1,778	2.53	1.80	2.16
Beijing	170	1,485	11,351	8.69	7.82	8.25	490	872	1,538	2.24	2.12	2.18
Tianjin	299	1,112	9,072	5.18	8.08	6.65	439	724	1,043	1.94	1.36	1.65
Liaoning	218	815	6,956	5.20	8.27	6.75	1,932	3,394	4,22	2.19	0.81	1.49
Jiangsu	131	310	5,792	3.37	11.45	7.41	3,739	5,834	7,468	1.73	0.92	1.31
Zhejiang	112	274	5,921	3.50	12.06	7.77	2,213	3,751	4,894	2.05	0.99	1.51
Guangdong	101	532	7,1	6.60	10.07	8.35	3,17	5,593	10,022	2.21	2.18	2.20
Shangdong	91	286	4,652	4.50	10.88	7.71	4,827	7,16	9,248	1.53	0.95	1.23
Fujian	102	234	4,195	3.25	11.28	7.26	1,27	2,446	3,535	2.55	1.37	1.95
Guangxi	67	202	1,662	4.34	8.12	6.25	1,943	3,402	4,66	2.18	1.17	1.66
Hebei	125	341	3,359	3.94	8.84	6.41	3,272	5,057	6,851	1.69	1.13	1.40
Mean	167.82	775.91	7,603.91	5.11	9.54	7.33	2,169.82	3,575.55	5,023.36	2.08	1.35	1.70
Median	125.00	341.00	5,921.00	4.50	8.84	7.41	1,943.00	3,402.00	4,660.00	2.18	1.17	1.65
Standard deviation	109.38	830.58	5,932.76	1.82	1.63	0.73	1,450.00	2,171.69	3,060.77	0.33	0.48	0.36
Central												
Heilongjiang	238	399	2,608	2.01	7.20	4.62	1,111	3,13	3,82	4.06	0.74	2.36
Jilin	153	324	3,237	2.93	8.90	5.93	1,065	2,149	2,715	2.74	0.87	1.78
Hubei	90	215	2,524	3.41	9.55	6.49	2,751	4,575	5,71	1.98	0.82	1.39
Shanxi	116	322	2,457	4.00	7.82	5.93	1,395	2,424	3,355	2.15	1.21	1.67
Hunan	86	211	1,809	3.51	8.28	5.92	3,271	5,166	6,326	1.77	0.75	1.25
Anhui	78	120	1,349	1.67	9.38	5.53	2,966	4,713	6,12	1.80	0.97	1.38
Jiangxi	114	179	1,658	1.75	8.59	5.18	1,656	3,183	4,307	2.54	1.13	1.82
Henan	83	157	1,905	2.48	9.69	6.09	4,371	7,067	9,38	1.87	1.05	1.45
Inner Mongolia	173	300	3,482	2.14	9.50	5.83	716	1,823	2,386	3.66	1.00	2.30
Mean	125.67	247.44	2,336.56	2.66	8.77	5.72	2,144.67	3,803.33	4,902.11	2.51	0.95	1.71
Median	114.00	215.00	2,457.00	2.48	8.90	5.92	1,656.00	3,183.00	4,307.00	2.15	0.97	1.67
Standard deviation	53.35	92.63	719.93	0.84	0.87	0.55	1,242.15	1,707.73	2,214.94	0.84	0.17	0.40
West												
Sichuan	171	488	5,402	4.12	9.31	6.73	6,405	9,707	11,006	1.61	0.47	1.03
Xinjiang	166	260	2,519	1.74	8.77	5.27	465	233	2,008	-2.62	8.30	2.80
Qinghai	101	376	2,003	5.19	6.39	5.80	161	365	543	3.20	1.48	2.32
Ningxia	126	403	3,006	4.57	7.73	6.17	142	356	595	3.60	1.92	2.74
Gansu	125	322	2,315	3.71	7.58	5.66	1,065	1,87	2,919	2.19	1.66	1.92
Shaanxi	85	322	2,314	5.26	7.58	6.43	1,528	2,779	3,718	2.33	1.08	1.69
Yunnan	70	178	1,379	3.65	7.88	5.78	1,695	3,091	4,442	2.34	1.35	1.83
Guizhou	123	248	1,563	2.73	7.06	4.91	1,49	2,686	3,73	2.29	1.22	1.75
Mean	120.88	324.63	2,562.60	3.87	7.79	5.84	1,618.88	2,635.88	3,620.13	1.87	2.19	2.01
Median	124.00	322.00	2,314.50	3.91	7.65	5.79	1,277.50	2,278.00	3,318.50	2.31	1.42	1.88
Standard deviation	35.59	97.86	1,259.11	1.20	0.92	0.60	2,031.27	3,092.53	3,315.74	1.92	2.51	0.59
Total 28 provinces												
Mean	140.86	477.11	4,470.46	3.97	8.79	6.39	2,004.32	3,380.29	4,583.46	2.15	1.46	1.79
Median	119.50	316.00	2,807.00	3.68	8.44	6.21	1,592.00	3,110.50	4,020.00	2.19	1.13	1.72
Standard deviation	78.07	566.90	4,494.13	1.71	1.40	0.99	1,538.61	2,308.62	2,856.81	1.13	1.41	0.45

[a] In Yuan/person at constant prices of 1952.
[b] In 10,000 persons.

Table 2: Transition probability matrix and ergodic distribution, per capita income (GDP/N), unweighted, 5 year transitions, limits all years

(Number of Observations)	Upper limit, all years:				
	0.919	0.960	0.990	1.061	Max.
(282)	0.82	0.15	0.01	0.01	0.01
(274)	0.15	0.62	0.19	0.02	0.02
(287)	0.02	0.21	0.58	0.18	0.00
(280)	0.00	0.02	0.21	0.68	0.09
(276)	0.00	0.01	0.00	0.10	0.89
Initial Distribution	0.18	0.21	0.11	0.29	0.21
Final Distribution	0.14	0.25	0.14	0.21	0.25
Ergodic Distribution	0.19	0.20	0.20	0.22	0.20

a)1952-2005

(Number of observations)	Upper limit, all years:				
	0.919	0.960	0.990	1.061	Max.
(121)	0.68	0.27	0.03	0.02	0.00
(165)	0.18	0.57	0.22	0.02	0.01
(94)	0.09	0.34	0.33	0.25	0.00
(133)	0.00	0.04	0.17	0.68	0.11
(130)	0.00	0.01	0.00	0.14	0.86
Initial Distribution	0.18	0.21	0.11	0.29	0.21
Final Distribution	0.25	0.14	0.25	0.18	0.18
Ergodic Distribution	0.26	0.28	0.14	0.19	0.14

b) 1952-1978

(Number of observations)	Upper limit, all years:				
	0.919	0.960	0.990	1.061	Max.
(142)	0.93	0.07	0.00	0.00	0.00
(90)	0.07	0.78	0.12	0.01	0.02
(180)	0.00	0.16	0.68	0.15	0.01
(128)	0.00	0.00	0.20	0.73	0.08
(132)	0.00	0.01	0.00	0.06	0.93
Initial Distribution	0.25	0.14	0.25	0.18	0.18
Final Distribution	0.14	0.25	0.14	0.21	0.25
Ergodic Distribution	0.11	0.14	0.12	0.23	0.41

c) 1978-2005

Table 3: Transition probability matrix and ergodic distribution, per capita income (GDP/N), GDP-weighted, 5 year transitions, limits all years

(Share of GDP)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.14)	0.80	0.18	0.01	0.00	0.00
(0.21)	0.13	0.68	0.15	0.01	0.02
(0.17)	0.03	0.21	0.57	0.19	0.00
(0.21)	0.00	0.03	0.18	0.71	0.08
(0.27)	0.00	0.01	0.00	0.09	0.90
Initial Distribution	0.13	0.19	0.08	0.36	0.23
Final Distribution	0.06	0.13	0.06	0.26	0.49
Ergodic Distribution	0.19	0.23	0.14	0.20	0.25

a) 1952-2005

(Share of GDP)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.15)	0.70	0.27	0.03	0.01	0.00
(0.24)	0.19	0.58	0.22	0.00	0.01
(0.17)	0.12	0.28	0.44	0.16	0.00
(0.19)	0.00	0.06	0.17	0.68	0.09
(0.25)	0.00	0.02	0.00	0.12	0.87
Initial Distribution	0.13	0.19	0.08	0.36	0.23
Final Distribution	0.16	0.19	0.21	0.17	0.27
Ergodic Distribution	0.38	0.34	0.16	0.08	0.04

b) 1952-1978

(Share of GDP)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.12)	0.92	0.08	0.00	0.00	0.00
(0.19)	0.03	0.83	0.09	0.01	0.04
(0.17)	0.00	0.15	0.67	0.18	0.00
(0.23)	0.00	0.00	0.13	0.80	0.08
(0.29)	0.00	0.00	0.00	0.08	0.92
Initial Distribution	0.16	0.19	0.21	0.17	0.27
Final Distribution	0.06	0.13	0.06	0.26	0.49
Ergodic Distribution	0.01	0.03	0.02	0.37	0.57

c) 1978-2005

Table 4: Transition probability matrix and ergodic distribution, per capita income (GDP/N), population-weighted, 5 year transitions, limits all years

(Share of population)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.28)	0.81	0.16	0.01	0.01	0.01
(0.24)	0.21	0.57	0.18	0.01	0.03
(0.19)	0.03	0.20	0.57	0.21	0.00
(0.18)	0.00	0.02	0.18	0.73	0.06
(0.13)	0.00	0.01	0.00	0.10	0.89
Initial Distribution	0.22	0.28	0.09	0.21	0.20
Final Distribution	0.15	0.21	0.09	0.28	0.26
Ergodic Distribution	0.17	0.14	0.12	0.30	0.26

a) 1952-2005

(Share of population)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.26)	0.69	0.26	0.03	0.02	0.00
(0.37)	0.23	0.55	0.21	0.00	0.01
(0.16)	0.13	0.30	0.37	0.20	0.00
(0.11)	0.01	0.06	0.19	0.69	0.05
(0.10)	0.00	0.04	0.00	0.11	0.85
Initial Distribution	0.22	0.28	0.09	0.21	0.20
Final Distribution	0.33	0.10	0.25	0.20	0.12
Ergodic Distribution	0.42	0.30	0.14	0.10	0.04

b) 1952-1978

(Share of population)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(0.28)	0.92	0.08	0.00	0.00	0.00
(0.11)	0.11	0.76	0.09	0.01	0.02
(0.21)	0.00	0.12	0.69	0.19	0.00
(0.24)	0.00	0.00	0.13	0.80	0.06
(0.16)	0.00	0.00	0.00	0.09	0.91
Initial Distribution	0.33	0.10	0.25	0.20	0.12
Final Distribution	0.15	0.21	0.09	0.28	0.26
Ergodic Distribution	0.02	0.02	0.02	0.43	0.51

c) 1978-2005

Table 5: Transition probability matrix and ergodic distribution, per capita income (GDP/N), physically contiguous-conditioned, 5 year transitions, limits all years

(Number of observations)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(268)	0.79	0.17	0.03	0.01	0.00
(308)	0.15	0.64	0.17	0.03	0.01
(198)	0.05	0.24	0.48	0.21	0.02
(417)	0.00	0.04	0.12	0.76	0.07
(206)	0.00	0.01	0.01	0.11	0.87
Initial Distribution	0.14	0.18	0.29	0.21	0.18
Final Distribution	0.18	0.14	0.32	0.21	0.14
Ergodic Distribution	0.22	0.23	0.14	0.26	0.15

a) 1952-2005

(Number of observations)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(107)	0.79	0.11	0.07	0.02	0.01
(119)	0.22	0.48	0.23	0.08	0.00
(91)	0.06	0.35	0.27	0.31	0.01
(227)	0.01	0.03	0.10	0.76	0.10
(99)	0.00	0.02	0.00	0.15	0.82
Initial Distribution	0.14	0.18	0.29	0.21	0.18
Final Distribution	0.21	0.29	0.07	0.29	0.14
Ergodic Distribution	0.26	0.15	0.11	0.34	0.14

b) 1952-1978

(Number of observations)	Upper limit, all years: 0.919	0.960	0.990	1.061	Max.
(142)	0.79	0.19	0.01	0.01	0.00
(177)	0.09	0.80	0.11	0.00	0.00
(96)	0.00	0.10	0.73	0.14	0.03
(159)	0.00	0.02	0.13	0.86	0.00
(96)	0.00	0.00	0.00	0.01	0.99
Initial Distribution	0.21	0.29	0.07	0.29	0.14
Final Distribution	0.18	0.14	0.32	0.21	0.14
Ergodic Distribution	0.04	0.20	0.24	0.26	0.26

c) 1978-2005

Table 6: Mobility indices (μ_1)[a]

Transition matrix	1952-1978	1978-2005	1952-2005
Unweighted	0.737	0.605	0.674
GDP-weighted	0.732	0.611	0.671
Population-weighted	0.755	0.614	0.670
Physically contiguous-conditioned	0.789	0.644	0.695

a See main text for definition of μ_1

Table 7: Transition path analysis (asymptotic half life of convergence)[a]

Transition matrix	1952–1978	1978–2005	1952–2005
Unweighted	16.795	29.820	15.044
GDP-weighted	52.627	22.414	19.541
Population-weighted	23.821	31.544	13.658
Physically contiguous-conditioned	9.762	15.218	11.609

a See main text for definition of *H -L*

Figure 1: GDP/N, densities, 1952 vs. 1978 vs. 2005

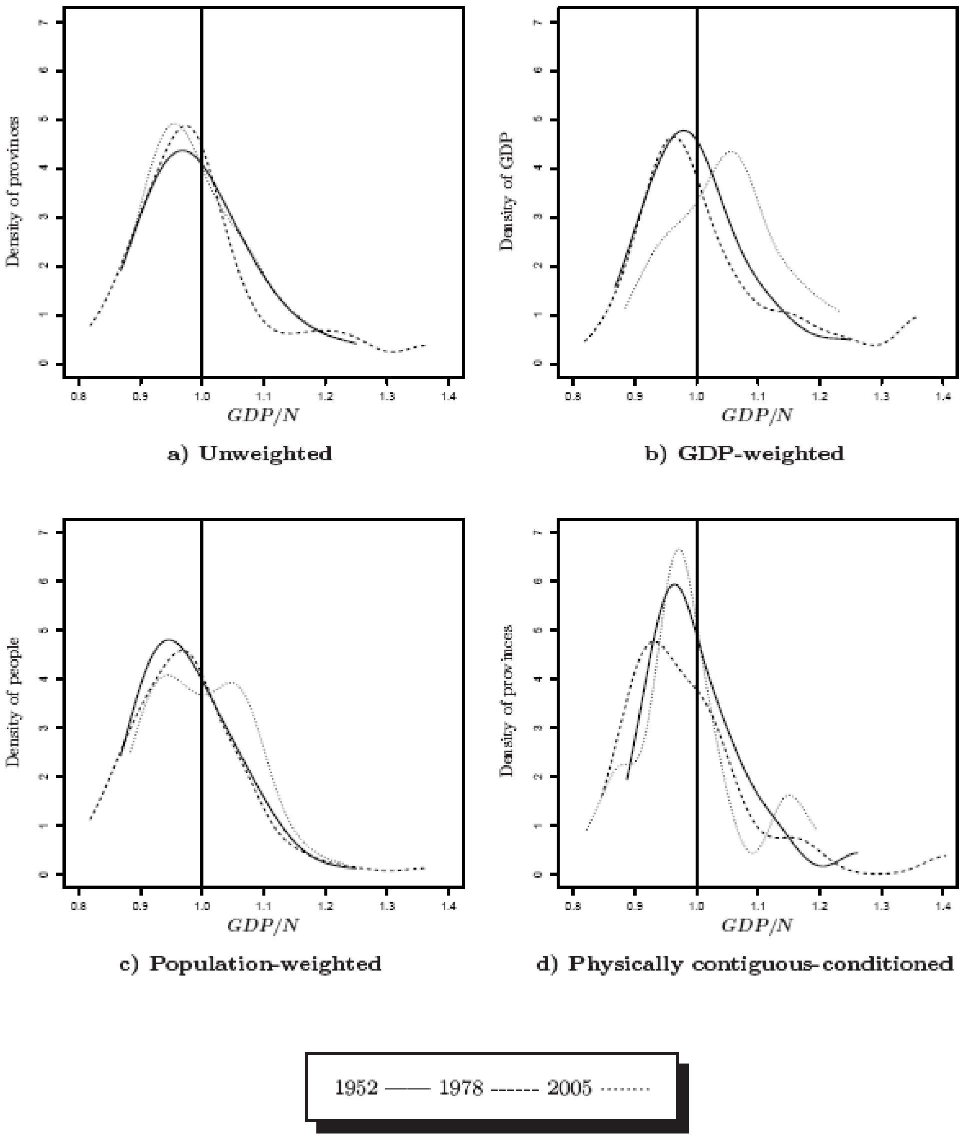
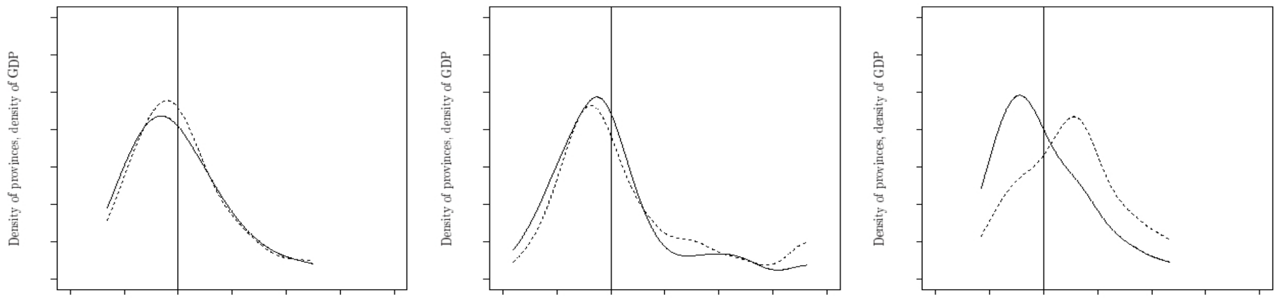


Figure 2: GDP/N, densities, unweighted vs. GDP-weighted



a) 1952 **b) 1978** **c) 2005**

Unweighted —— GDP-weighted ------

Figure 3: GDP/N, densities, unweighted vs. population-weighted

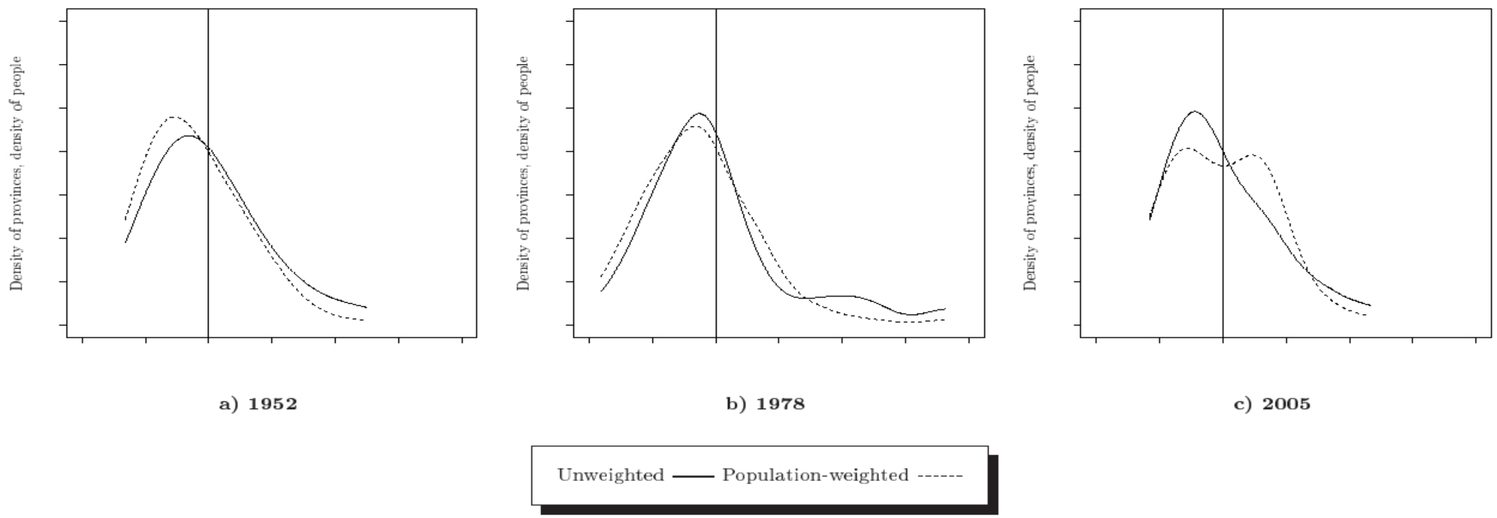


Figure 4: GDP/N, densities, unweighted vs. physically contiguous-conditioned

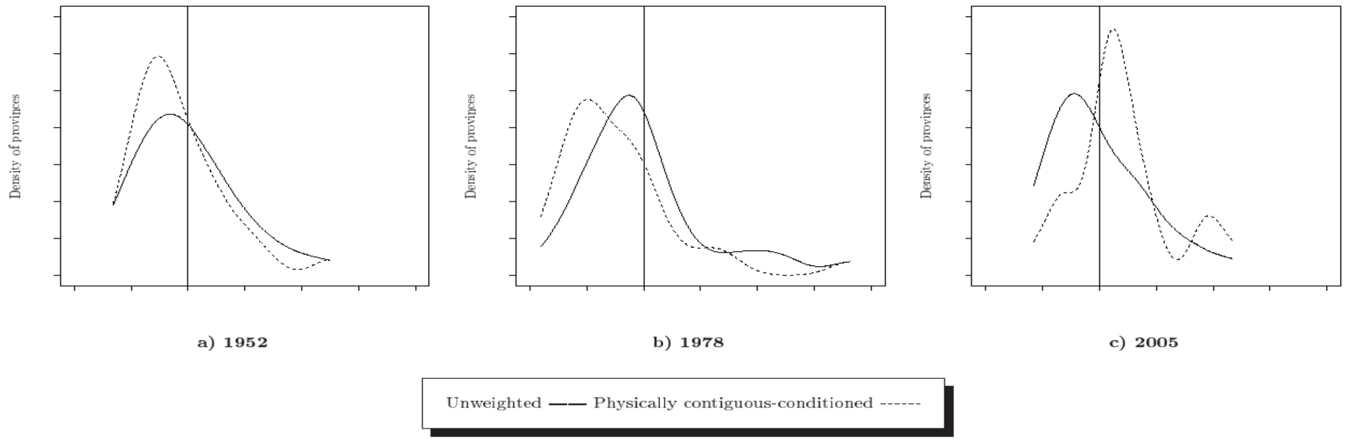
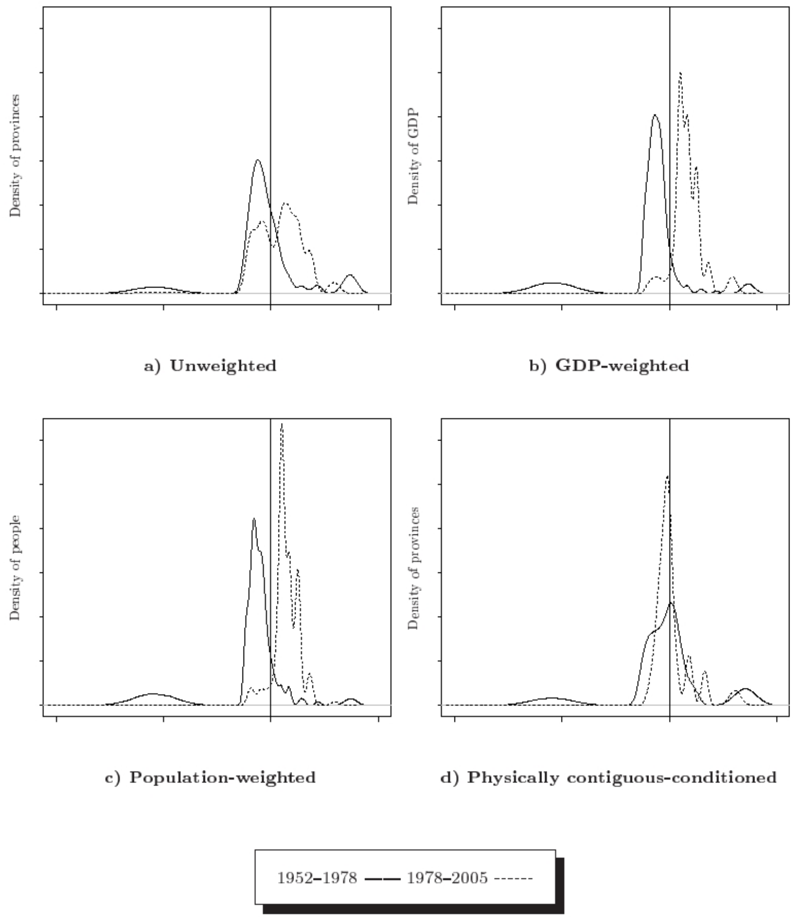


Figure 5: GDP/N, ergodic distributions, 1952–1978 vs. 1978–2005



References

Alesina, A. and Perotti, R. (1993). 'Income distribution, political instability, and investment.' Working Paper 4486, National Bureau of Economic Research.

Alesina, A. F. and Rodrik, D. (1994). 'Distributive politics and economic growth.' *The Quarterly Journal of Economics* 109, pp.465-490.

Bai, C. E., Hsieh, C., and Qian, Y. (2006). 'The return to capital in China.' Technical Report 12755, National Bureau of Economic Research.

Barro, R. J. and Sala-i-Martin, X. (1992). 'Convergence.' *Journal of Political Economy* 100, pp.223–251.

Bhalla, A., Yao, S., and Zhang, Z. (2003). 'Regional economic performance in China.' *The Economics of Transition* 11, pp.25–39.

Bramall, C. (2000). 'Sources of Chinese Economic Growth, 1978–1996.' Studies on Contemporary China.Oxford University Press.

Brun, J. F., Combes, J. L., and Renard, M. F. (2002). 'Are there spillover effects between coastal and non-coastal regions in China?' *China Economic Review* 13, pp.161–169.

Bulli, S. (2001). 'Distribution dynamics and cross-country convergence: a new approach.' *Scottish Journal of Political Economy* 48, pp.226–243.

Caselli, F., Esquivel, G., and Lefort, F. (1996). 'Re-opening the convergence debate: a new look at cross-country growth empirics'. *Journal of Economic Growth* 1, pp.363–389.

Cetorelli, N. (2002). 'Could Prometheus be bound again? A contribution to the convergence controversy.' *Journal of Economic Dynamics and Control* 27, pp.29–50.

Chai, J. C. (1998). 'China: Transition to a Market Economy.' Studies on Contemporary China. Oxford University Press.

Chen, J. and Fleisher, B. (1996). 'Regional income inequality and economic growth in China.' *Journal of Comparative Economics* 22, pp.141–164.

Chow, G. (2006). 'Are Chinese official statistics reliable?' *CESifo Economic Studies* 52, pp.396–414.

De la Fuente, Á. (1997). 'The empirics of growth and convergence: A selective review.' *Journal of Economic Dynamics and Control* 21, pp.23–73.

Ding, L., Haynes, K., and Liu, Y. (2008). 'Telecommunications infrastructure and regional income convergence in China: panel data approaches.' *The Annals of Regional Science* 42, pp.843–861.

Durlauf, S. N. and Quah, D. T. (1999). 'The new empirics of economic growth.' In Handbook of Macroeconomics, volume 1A, pages 231–304. North Holland, Amsterdam.

Fujita, M. and Hu, D. (2001) 'Regional disparity in China 1985–1994: The effects of globalization and economic liberalization', *The Annals of Regional Science* 35, pp.3-37

Geweke, J., Marshall, R. C., and Zarkin, G. A. (1986). 'Mobility indices in continuous time Markov chains.' *Econometrica* 54, pp.1407–1423.

Gezici, F. and Hewings, G. J. D. (2007). 'Spatial analysis of regional inequalities in Turkey.' *European Planning Studies* 15, pp.383–403.

Goerlich, F. J. (2003). 'Weighed, kernel density estimators and convergence.' *Empirical Economics* 28, pp.335–351.

Gundlach, E. (1997). 'Regional convergence of output per worker in China: a neoclassical interpretation.' *Asian Economic Journal* 11, pp.423–442.

Härdle, W. and Linton, O. (1994). 'Applied nonparametric methods.' In Engle, R. and McFadden, D., editors, Handbook of Econometrics, volume 4. North Holland, Amsterdam.

Holz, C. A. (2005). 'China governance project: The institutional arrangements for the production statistics.' Statistics Working Papers 2005/1, OECD, Paris.

Islam, N. (2003). 'What have we learnt from the convergence debate?' *Journal of Economic Surveys* 17, pp.309–362.

Jian, T., Sachs, J., and Warner, A. (1996). 'Trends in regional inequality in China.' *China Economic Review* 7, pp.1–21.

Johnson, P. A. (2000). 'A nonparametric analysis of income convergence across the US states.' *Economics Letters* 69, pp.219–223.

Johnson, P. A. (2005). 'A continuous state space approach to "Convergence by parts"'. *Economics Letters* 86, pp.317–321.

Jones, C. I. (1997). 'On the evolution of the world income distribution.' *Journal of Economic Perspectives* 11, pp.19–36.

Kremer, M., Onatski, A., and Stock, J. (2001). 'Searching for prosperity.' *Carnegie-Rochester Conference Series on Public Policy* 55, pp.275–303.

Krugman, P. R. (1991). 'Increasing returns and economic geography.' *Journal of Political Economy* 99, pp. 483-499.

Krugman, P. R. (1993). 'Geography and Trade'. MIT Press.

Lamo, A. (2000). 'On convergence empirics: Some evidence for Spanish regions.' *Investigaciones Económicas* 24, pp.681–707.

Lardy, N. R. (1992). 'Foreign Trade and Economic Reform in China, 1978–1990.' Cambridge University Press.

Li, W. (1997). 'The impact of economic reform on the performance of Chinese state enterprises, 1980–1989.' *Journal of Political Economy* 105, pp.1080–1106.

Lin, J. Y. (1992). 'Rural reforms and agricultural growth in China.' *The American Economic Review* 82, pp. 34–51.

Maasoumi, E. and Wang, L. (2008). 'Economic reform, growth and convergence in China.' *Econometrics Journal* 11, pp.128–154.

Magrini, S. (1999). 'The evolution of income disparities among the regions of the European Union.' *Regional Science and Urban Economics* 29, pp.257–281.

Marshall, A. (1890). 'Principles of Economics.' Macmillan and Co.

Pedroni, P. and Yao, J. Y. (2006). 'Regional income divergence in China.' *Journal of Asian Economics* 17, pp. 294–315.

Quah, D. T. (1993a). 'Empirical cross-section dynamics in economic growth.' *European Economic Review* 37, pp.426–434.

Quah, D. T. (1993b). 'Galton's fallacy and tests of the convergence hypothesis.' *Scandinavian Journal of Economics* 95, pp.427–443.

Quah, D. T. (1996a). 'Aggregate and regional disaggregate fluctuations.' *Empirical Economics* 21, pp.137–159.

Quah, D. T. (1996b). 'Empirics for economic growth and convergence.' *European Economic Review* 40, pp.1353–1375.

Quah, D. T. (1996c). 'Regional convergence clusters across Europe.' *European Economic Review* 40, pp.951– 958.

Quah, D. T. (1996d). 'Twin Peaks: Growth and convergence in models of distribution dynamics.' *Economic Journal* 106, pp.1045–1055.

Quah, D. T. (1997a). 'Empirics for growth and distribution: Stratification, polarization and convergence clubs.' *Journal of Economic Growth* 2, pp.27–59.

Quah, D. T. (1997b). ‘Regional cohesion from local isolated actions. II. Conditioning.’ Discussion Paper 379, CEPR.

Raiser, M. (1998). ‘Subsidising inequality: Economic reforms, fiscal transfers and convergence across Chinese provinces.’ *Journal of Development Studies* 34, pp.1–26.

Redding, S. (2002). ‘Specialization dynamics.’ *Journal of International Economics* 58, pp.299–334.

Rozelle, S. (1994). ‘Rural industrialisation and increasing inequality: emerging patterns in China's reforming economy’, *Journal of Comparative Economics* 19, pp.362-91.

Sakamoto, H. and Islam, N. (2008). ‘Convergence across Chinese provinces: An analysis using Markov transition matrix.’ *China Economic Review* 19, pp.66–79.

Sala-i-Martin, X. (2006). ‘The world distribution of income: Falling poverty and... convergence, period.’ *Quarterly Journal of Economics* 121, pp.351–398.

Schultz, T. P. (1998). ‘Inequality in the distribution of personal income in the world: How it is changing and why.’ *Journal of Population Economics* 11, pp.307–344.

Shorrocks, A. F. (1978). ‘The measurement of mobility.’ *Econometrica* 46, pp.1013–1024.

Temple, J. (1999). ‘The new growth evidence.’ *Journal of Economic Literature* 37, pp.112–156.

Wang, Z. (2003). ‘Regional Divergence of per capita GDP in China: 1991-1999’. *Journal of Chinese Economic and Business Studies* 2, pp.39–53.

Weeks, M. and Yao, J. Y. (2003). ‘Provincial conditional income convergence in China, 1953–1997: A panel data approach.’ *Econometric Reviews* 22, pp.59–77.

Wei, Y. (1996) ‘Fiscal systems and uneven regional development in China, 1978–1991’, *Geoforum* 27, pp. 329-344

Yao, S. and Zhang, Z. (2001a). ‘On regional inequality and diverging clubs: a case study of contemporary China.’ *Journal of Comparative Economics* 29, pp.466–484.

Yao, S. and Zhang, Z. (2001b). ‘Regional growth in China under economic reforms.’ *Journal of Development Studies* 38, pp.167–186.